A NEUROCOGNITIVE PERSPECTIVE ON LANGUAGE ACQUISITION IN ULLMAN'S DP MODEL

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Abstract. In the last few decades, the studies in second language acquisition have not answered the question what mechanisms a human's brain uses to make acquisition of language(s) possible. A neurocognitive model which tries to address SLA from such a perspective was suggested by Ullman (2005; 2015), according to which, "both first and second languages are acquired and processed by well-studied brain systems that are known to subserve particular nonlanguage functions" (Ullman, 2005:141). The brain systems in question have analogous roles in their language and nonlanguage functions. This article is meant to critically analyse the suggested DP model within the context of neurocognitive studies of L2; and evaluate its contribution to the field of SLA studies.

Keywords: *neurolinguistics; declarative / procedural model of SLA; language acquisition.*

Готцева Маріана. Нейрокогнітивна перспектива оволодіння мови в декларативно-процедурній моделі Ульманна.

Анотація. Упродовж останніх декількох десятиліть дослідники в галузі оволодіння мови не спромоглися знайти відповідь на питання, які ж саме механізми людського мозку залучені під час оволодіння мови. Однією з нейрокогнітивних моделей, спрямованих на з'ясування питання оволодіння другої мови (SLA), слугує модель Ульманна (2005; 2015), згідно з якою «під час оволодіння та обробки і першої, і другої мови залучені добре вивчені системи мозку, що виконують також функції, не пов'язані з мовою» (Ullman, 2005:141). Зазначені системи здатні виконувати подібні мовні та немовні функції. Стаття має за мету критично проаналізувати запропоновану модель у контексті нейрокогнітивних досліджень другої мови, а також оцінити її внесок до галузі досліджень питання оволодіння другої мови (SLA).

Ключові слова: *нейролінгвістика, декларативна / процедурна модель оволодіння другої мови, оволодіння мови.*

1. Introduction

The neurocognitive bases of second language acquisition (SLA) have not been thoroughly investigated yet and the empirical research in this area is far from abundant. Therefore, it is not surprising that there are very few attempts to offer an integrative neurocognitive theory of SLA in relation to L1 acquisition in the context of the brain structure and functions. One such example is Ullman's DP model (2005; 2015) and although it has its own limitations, it contributes to the scientific attempt to shed more light on the process of language acquisition from a neurocognitive perspective. What is more, as Ullman claims, the DP model is capable of making "specific and novel predictions for language" (Ullman and Lovelett, 2016:1) by suggesting techniques for enhancing learning and memory.

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Ullman's Declarative / Procedural (DP) model focuses on two neural systems: the temporal-lobe substrates of declarative memory, responsible for the storage and use of knowledge of facts and events; and the network of specific frontal, basal-ganglia, parietal and cerebellar structures, underlying procedural memory, responsible for the learning and execution of sequential cognitive and motor skills. Both systems play a significant role in language acquisition and Ullman claims that there is sufficient empirical evidence from neuroimaging studies of normal language processing, and from developmental and adult-onset disorders, such as non-fluent and fluent aphasia, which supports his DP model (Ullman, 2004; 2015).

2. The Study

2.1. Brain organization and language domains

So far, numerous studies have tried to explain language learning by focusing on Broca's or Wernicke's areas of the neocortex. However, these neocortical areas are not autonomous, self-sufficient entities. They are elaborately connected to other brain structures, all of which cooperate to perform different functions. In this context, some researchers (Aboitiz, 1995; Aboitiz and Garcia, 1997; Aboitiz et al, 2006) propose that the neural device involved in language comprehension and production belongs to "a large-scale cortical network reciprocally connecting higher-order areas in the temporoparietal lobes with prefrontal areas – other components such as the basal ganglia and certain thalamic nuclei" (Aboitiz et al, 2006:4).

Ullman (2004:231) grounds his DP model on the same presumption of "commonalities between language and non-language domains". The topographical-like organization of the human brain includes sub-regions which perform analogous computations on different domains of information, but each sub-region has its own particular set of inputs and outputs. Such type of brain organization has been claimed for the cerebellum, for various sub-cortical structures, including the basal ganglia, and for certain cortical regions, especially in frontal cortex (Alexander, De Long & Strick, 1986; Middleton and Strick, 2000). This leads to the assumption that analogous computations may underlie a range of cognitive domains, including language. So, Ullman identifies cognitive domains that share communalities with language and by studying their underlying neural and computational systems, draws conclusions about the systems that subserve language. In other words, instead of exploring language from linguistic point of view only, he suggests making predictions about language "based solely on non-language theories and data" (Ullman, 2004).

2.2. The role of the two memory systems

Generally, the declarative memory system is defined as underlying "the learning, representation, and use of knowledge about facts (semantic knowledge) and events (episodic knowledge)" (Ullman, 2005). It is very important for learning arbitrary relations, that is, for the associative binding of information (Eichenbaum and Cohen, 2001). The knowledge stored in declarative memory is partly explicit, available to conscious awareness (Chun, 2000). The declarative memory system is subserved by medial temporal lobe regions: the hippocampal region (the dentate gyrus, the subicular complex, and the hippocampus itself), entorhinal cortex, perirhinal cortex, and parahippocampal cortex (Squire and Knowlton, 2000). The medial temporal structures consolidate and retrieve new memories (Eichenbaum and Cohen, 2001, Square and Knowlton, 2000). Memories seem to become independent of these structures and dependent on neocortical regions in the temporal lobes. Other brain structures which also play a role in declarative memory include portions of ventro-lateral prefrontal cortex, which seems to participate in a way in the selection or retrieval of declarative memories, while parts of the right cerebellum may underlie searching for this knowledge (Buckner and Wheeler, 2001).

The ventral stream system is rooted in inferior and lateral temporal-lobe structures and underlies the formation of perceptual representations of objects and their relations. These representations enable the recognition and identification of objects and the long-term storage of knowledge about objects (Goodale, 2000). Thus, the ventral system is a memory-based one, which feeds representations into the long-term (declarative) memory and compares these representations with new ones.

Later research into the declarative memory system has found out that it can underlie even implicit knowledge of different kind (Henke, 2010; Ullman and Pullman, 2015), despite the fact that it is the only system underlying explicit knowledge and representing arbitrary associations.

The term “procedural memory system” as used by Ullman, refers to “the entire system involved in the learning, representation and use of the relevant knowledge, not just to those parts of the system underlying the learning of new memories” (Ullman, 2004: 237). This system subserves the learning of new, as well as the control of already established, sensori-motor and cognitive skills, such as riding a bicycle, for example. It is considered to be an implicit memory system as neither the knowledge learned, nor the process of learning is consciously accessible. Normally, a person is not aware of the nature of the knowledge and often he / she does not remember when and how the skill was learned. A large number of activities in our daily lives are learned and performed automatically and unconsciously. For example, when a musician is playing some musical instrument, he is not aware of the position of his fingers. It is the same when a person speaks his native language: he does not consciously move the oral articulatory organs, neither does he think of how to construct his sentences. These are automatic motor or cognitive behaviours. The procedural memory system subserves aspects of the learning and processing of context-dependent stimulus-response connections (Packard and Knowlton, 2002). Compared to the fast learning subserved by the declarative memory, learning in procedural memory system is gradual and ongoing, based on multiple presentations of stimuli and responses. The relations within this system are rigid, inflexible and not influenced by other mental systems. Procedural memory system, unlike declarative memory, seems to be informationally encapsulated. Rules apply quickly and automatically as the response is triggered by a stimulus rather than being under conscious control (Square and Zola, 1996).

The procedural memory system is supported by a network of brain structures: the frontal/ basal-ganglia circuits; portions of parietal cortex, superior temporal cortex and the cerebellum (Hikosaka et al., 2000). Both anatomical and functional evidence in non-human primates supports the existence of basal ganglia thalamocortical circuits that project to Broca's area. Although there is no direct anatomical data to prove such circuits in humans, Ullman considers that indirect anatomical evidence supports its presence.

The close links between the basal ganglia and Broca's area are further supported by the fact that the two structures underlie a common set of functions. In the language domain, both structures have been implicated in lexical selection or retrieval (Crosson et al., 2003); in aspects of grammar – both morphology and syntax (Embick et al., 2000; Moro et al., 2001; Friederici, 2002); and in phonology (Zurowski et al., 2002; Crosson et al., 2003). Other functions and domains also appear to be subserved by both structures: the selection or retrieval of conceptual / semantic knowledge; working memory; sequencing; action control and motor function; learning in procedural memory; and aspects of temporal processing.

The co-occurrence of these essentially different functions within posterior Broca's area and within the basal ganglia, leads to two assumptions: there is either functional sub-categorization within the basal ganglia thalamocortical circuitry passing through posterior Broca's area, so that different portions of this circuit (sub-channels) subserve each of these functions, or these distinct functions represent different aspects of the same underlying function. Ullman concludes that this underlying function can be characterized as procedural memory (Ullman, 2005). It appears then that "procedural memory is a brain system specialised across domains (including motor, music, language), whose function is integrally bound up both in the timing of the sequences it subserves, and in the maintenance and manipulation of these sequences in working memory" (Ullman, 2004; Ullman and Pierpont, 2005).

However, nothing implies that all the parts of this procedural system should have the same functions. In fact, basal ganglia and Broca's area seem to specialize in distinct functions. While basal ganglia play a role in the acquisition of grammatical and other procedural knowledge, the use of this knowledge depends on the posterior portion of Broca's area. This is supported by evidence from research on grammatical deficit in adults as a result of damage of Broca's area but not of the basal ganglia (Alexander, 1997; Fabbro et al., 1996; Ullman, 2004). Abnormalities in the basal ganglia, found in certain developmental disorders, are linked to grammatical disfunction, which confirms the role of the basal ganglia in learning, which is not their only function. They have also been involved in aspects of selection, timing, working memory and other functions, such as lexical / semantical retrieval. The latter has been supported by the findings of neuroimaging and ERP studies which have implicated the basal ganglia in aspects of sentence processing in rapidly presented speech (Peele et al., 2004) and in processing of errors that require reanalysis (Friederici et al., 1999, 2003; Moro et al., 2001).

The declarative and procedural memory systems interact in various ways. Together they form a dynamically interacting network which supports both co-operative and competitive learning and processing, so that the memory functions can be optimized (Poldrack and Packard, 2003). The two systems complement each other in acquiring the same analogous knowledge: the declarative memory acquires the knowledge initially, due to its fast learning abilities; while the procedural memory might acquire the same or analogous knowledge, but gradually. On the other hand, there is evidence from animal and human studies that the two systems can act competitively: learning in one system results in depressing the functionality of the other (Poldrack and Packard, 2003). The two systems can also function differently across individuals. Ullman explains that with the direct anatomical projection between the systems and a role for acetylcholine and estrogen, which can influence the individual performance on tasks within one system or the other (Ullman, 2004).

2.3. The DP Model and language acquisition

In Ullman's Declarative / Procedural Model, the two memory systems have analogous roles in linguistic and non-linguistic functions. They are supposed to interact both cooperatively and competitively in language acquisition and use. In a situation of young children, acquiring their L1, initially they learn both idiosyncratic and complex forms through the system of declarative memory, while the procedural system gradually acquires the grammatical knowledge underlying rule-governed combinations. The fact that the two systems function competitively is supported by evidence which shows that if functionality in one of the systems increases, this suppresses the other system and vice versa. For instance, the increased declarative memory in childhood may facilitate lexical acquisition but depress the procedural learning of grammatical knowledge (Di Giulio et al., 1994).

However, there are a few inconsistencies the DP model contains in relation to claims about the specificity of the neural basis of grammar. Grodzinski (2000), for example, challenges the assumption that Broca's area is dedicated to language and performs a certain set of language computations. In his view, this might be true about another set of language computations but not the ones claimed by the DP model. The model is also inconsistent with the claims of some connectionist models which deny grammatical composition (Joanisse and Seidenberg, 1999). These models deny the existence of empirical evidence for associations between grammatical domains and procedural memory, or dissociations between these and lexical and declarative memory. The main objection to the DP model concerns the parsing of linguistic knowledge between the two memory systems as the process might be much more complex than a "one-to-one linkage of lexical acquisition to declarative memory and grammar learning to procedural memory" (Dionne et al., 2003; Devescovi et al., 2005; Ferman et al., 2009). What is more, declarative knowledge might be converted into procedural knowledge and vice-versa as a result of accumulating experience (Anderson et al., 2004; Sun and Zang, 2004).

The DP model contradicts the claims that after a certain age the acquisition of a second language is not likely to take place and L2 cannot be attained to the level of proficiency of young learners (Birdsong, 1999). It admits that the acquisition of grammatical-procedural knowledge in L2 adults is more problematic than the acquisition of lexical-declarative knowledge, compared to L2 young learners but explains this with factors such as decreased rule-abstraction abilities "due to augmented working memory capacity" (Newport, 1993), the attenuation of procedural memory, and the enhancement of declarative memory. A lot of evidence from humans and animals suggests that motor skill learning, which is usually associated with the procedural system, is strongly affected by "early critical period effects" (Fredriksson, 2000; Shlaug, 2001). These changes in both types of memory might be partly explained by the increasing levels of estrogen in childhood / adolescence as estrogen may inhibit in a way the procedural memory and enhance declarative memory (Calabresi et al., 2000; Ullman, 2004). Ullman (2005) suggests that learning in one system might depress the functionality of the other: the improvements in declarative memory in the childhood may be accompanied by an attenuation of procedural learning abilities. It could be expected that young adult L2 learners can memorize complex linguistic forms, normally computed compositionally by L1speakers. What leads to productivity in L2 learners might be the associative properties of lexical memory (Pinker, 1994) or learning rules in pedagogical context. This could differ significantly from grammatical-procedural computations in L1.

The DP model also assumes that the memorizing complex forms and rules in the declarative memory may lead to a comparatively high degree of proficiency, depending on the amount and type of L2 exposure, as well as on individual differences in declarative memory abilities. However, as not all types of grammatical knowledge are equally "learnable" in declarative memory, certain complex forms are expected to cause more difficulties. The limitations of lexical-declarative memory will, inevitably, lead to limited grammatical proficiency. However, multiple studies in adult L2 acquisition of non-linguistic skills by procedural memory show that a lot of practice might lead to improved performance. Therefore, Ullman (2005; 2016) concludes that sufficient practice in L2 will highly increase the level of proficiency of L2 adult learners. Certainly, this will depend on the individual intrinsic procedural learning abilities.

The claims and predictions about young L2 adults, though, differ for L2 adults. The ability to learn new information in the declarative memory deteriorates in early adulthood and shows notable losses in old age (Park et al., 2002). This might be explained with the decreasing levels of estrogen with age. Consequently, this may lead to more difficulties with both procedural and declarative aspects of L2 acquisition, compared to young L2 learners.

The DP model suggests an interesting mechanism which explains these differences. At lower levels of L2 experience, declarative memory subserves the learning and use not only of idiosyncratic lexical knowledge but of complex linguistic representations as well. Due to the deterioration of declarative memory, older learners are expected to have particular difficulties in acquiring a second language even to low proficiency. At higher levels of L2 experience, the procedural memory system is supposed to be able to acquire grammatical knowledge, although this might be more difficult for older L2 learners, resulting in a neurocognitive pattern, similar to that of L1, that is, with idiosyncratic lexical knowledge stored in declarative memory, and ruled-governed complex forms composed by the procedural system. As a result, dissociations between simple and complex forms might be expected in high experience L2 and in L1 but not so in low-experience L2 (Ullman, 2005). The conclusion drawn claims that "the use of complex forms should depend more on declarative memory brain structures in low experience L2 than in L1 or high-experience L2, in which complex forms should show a greater dependence on procedural memory brain structures. In contrast, idiosyncratic lexical knowledge should be stored in declarative memory in all individuals, and therefore no lexical dissociations between L1 and either low- or high-experience L2 are expected" (Ullman, 2005:154).

Although Ullman uses various kinds of empirical evidence in support of the DP model (Ullman, 2005), such as L1 aphasia and L2 brain damage; PET, fMRI, and EPR of L1 and L2 speakers; not all the claims of the model are convincingly proved. It cannot be denied, though, that the DP model attracts attention by claiming that L2 learners could ultimately become L1-like in terms of proficiency and underlying neurocognitive correlates, which contradicts the critical period hypothesis (Birdsong, 1999).

Another interesting point the DP model makes, is the potential role for pharmacological agents in SLA. Again, it needs further research and testing. On the other hand, the model might contribute to the understanding of the much studied distinction between explicit and implicit knowledge in SLA (N.C.Ellis, 1994, 2002; R.Ellis et al., 2009), although it is impossible to draw simple parallels between the explicit-implicit and declarative-procedural distinctions.

Compared to other neurocognitive perspectives of SLA, the DP model shares similarities with the view of Friederici and her colleagues, based on their fMRI and ERP data, who have also come to the conclusion that "low proficiency L2 learners do not have the neurocognitive abilities of native speakers for automatic parsing and syntactic structure building in sentence comprehension, which are assumed to depend on BA 44 and certain other structures of L1" (Friederichi et al., 2003; Opitz and Friederichi, 2003). But they also assume that low proficiency learners initially compensate for this lack by relying on medial and lateral temporal lobe structures, and probably on strategy-dependent compensatory right-hemisphere processes (Hanhe and Friederichi, 2001; Optiz and Friederichi, 2003). As L2 proficiency increases (with more exposure to, and experience with the language), the medial and lateral temporal lobe involvement decreases while BA 44 involvement increases (Optiz and Friederichi, 2003). As for the conceptual-semantic integration in L2 learners, it seems to remain, to a large extent, L1-like (Hahne and Friederichi, 2003). Therefore, Friederichi's data and conclusions confirm the main claim of Ullman's DP model.

The latest contribution of Ullman's DP model (Ullman and Lovelett, 2016) also includes suggestions of enhancing L2 acquisition through interventions and techniques for improving the function of one or both memory systems. These include spaced repetition of the learned item within certain periods of time (Cepeda *et al,* 2008); retrieval practice - retrieving information from memory instead of re-studying it (Roediger and Butler, 2011); deep encoding, and so on, all of which are claimed to benefit the declarative memory. However, research demonstrating empirical evidence for these claims is still scarce and poses a potential field for further investigation.

3. Conclusions

Despite certain limitations, the DP model is worthy as an attempt to research SLA from a neurocognitive perspective, in relation to L1 acquisition, and in the context of the brain structure and functions. Its focus on the two memory systems (declarative and procedural), which seem to be engaged with the acquisition not only of language, but numerous other fields of knowledge and skills, could be interpreted as an attempt to explain language acquisition as one of the many brain functions subserved by these memory systems and to understand better the brain mechanisms involved in SLA.

In certain respects, the DP model poses similar claims for both L1 and L2 acquisition. Most of the learning, storage and usage of idiosyncratic knowledge in language (both L1 and L2) is claimed to take place in the declarative memory system, which is also responsible for storing knowledge about morphological inflectional and derivational peculiarities, as well as idiomatic meanings (Ullman and Lovelett, 2016).

The most striking claim of the model, however, is the expressed possibility of L2 learners to ultimately become L1-like in terms of proficiency and underlying neurocognitive correlates, which challenges the critical period hypothesis. Other interesting points the DP model makes, are the potential role for pharmacological agents in SLA, and the enhancement of language learning / acquisition through certain techniques and interventions, aimed at enhancing the declarative memory.

It could be concluded that Ullman's DP model contributes to the understanding of the brain mechanisms underlying human's ability to acquire languages, as well as the distinction between explicit and implicit knowledge in SLA from a neurocognitive perspective.

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