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Behavioral and Neural Approaches to Target Language Use in Investigating Explicit and Implicit Learning

Haemoon Lee*
(Sungkyunkwan University)

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L2 learners' target language use has been examined for various purposes, including assessment of the learners' proficiency and examination of the process of language learning. That is, target language use in the real life tasks on the level as automatized as that of native speakers represents the goal of L2 learning. More importantly, however, target language use has been proposed as a process that provides the learning opportunities, particularly since 1980s by communicative approach to SLA. Until the learners can communicate effortlessly without being conscious of the form of the language, how learners' attention and awareness are or should be directed to the language form and meaning has been an important issue among the recent SLA theories, summarized as the interface/non-interface debate. This paper discusses how different major SLA theories view learners' attention and awareness of language form during language use and how it has been measured for both process and result research. Finally, a recent neurobiolobical SLA model is introduced in terms of its methodological and theoretical contribution to SLA research.

Key words: language use, explicit and implicit learning, attention and awareness, automatization, neurobiological model, SLA methodologies

1. INTRODUCTION

Target language use has been considered important ever since communicative approach (CA) was introduced to second language learning and teaching in 1980s. In CA framework, communicative competence replaced linguistic competence as a true functional goal of language acquisition. And in order to build communicative competence, meaning-oriented

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communication was emphasized, whereas the formal grammar instruction was de-emphasized.

However, it has not been clear from a cognitive view why and how such meaningful language use contributes to SLA precisely. Many controversies are left unresolved such as whether it is harmful to pay attention to the formal aspect of language; whether L2 grammar is learned inadvertently while learners are focusing on meaning; more fundamentally, whether learners are really not aware of the language form during the meaningful language use; or whether they are conscious of the form even during the meaning-oriented language use, particularly more in case of adult L2 learners who are cognitively mature enough to pursue the formal aspect of a language by themselves. These questions are culminated into the core cognitive question of how form-meaning mapping occurs and is consolidated into long-term automatized memory through communicative language use which prioritizes meaning-processing.

Long (1990) proposed that any SLA theory should answer at least a few critical questions of SLA, one of which is the role of language use for SLA. As acknowledged, language use is often proposed directly to play a certain role for SLA or its role can be only inferred from other main theoretical constructs. This paper aims at discussing (1) how different theories assign a different role to target language use, and (2) whether their methodological research tools were reliable for testing conflicting proposals, including the most recent technical and scientific methods that involve other fields of study such as psychology, biology, and neurology, and finally, (3) a recent neurobiological approach will be discussed in terms of how it expands and converges with the current SLA theories regarding automatized or non-automatized language use. In-depth discussion of the various theoretical meanings of target language use is considered to help both researchers and practitioners decide their specific positions regarding the value of language use. Such a discussion is opportune because it was not clear why and how to implement communicative L2 curriculum, though communicative language use has always had the paramount value since 1980s. It is probably because it has been rare that theories were compared together in terms of the role of language use proposed or implied. Therefore, in this paper theories will be compared centering on the role of language use, as well as their newly updated research methods, in order to establish communicative language use as a common standard for discussing and comparing SLA theories.

2. TRADITIONAL THEORIES OF SLA

Major SLA theories are grouped into three, depending on their view on the role of language use. The first group, nativism and connectionism, proposes that the role of language use is mainly for implicit learning. Nativism adopted by Krashen's (1982, 1985) input hypothesis proposes that language use provides the learners with exposure to the language input for activating Universal Grammar (UG) while learners are unaware of the language form acquired. Input comprehended was proposed as a necessary and sufficient condition, while form-oriented conscious learning was deemphasized even in the classrooms. Formal learning was even warned for producing over-users of monitor. Connectionism also argues that language use contributes to implicit learning but from a quite different reason (Ellis, 2002, 2003). It proposes that language use provides repeated exposure to language form for forming association network, or statistical learning. While learners are not conscious of form-meaning relationship each time, the form-form sequences that occur in high frequency in the input results in formulaic chunks which are acknowledged as correct, natural, or grammatical. High frequency of input in the same sequence is crucial for connectionism, whereas nativism and input hypothesis do not consider it as critical as innate language acquisition device, though both theories are proposing language use is the required for implicit language learning.

The second group of SLA theories proposes that the role of language use is for Focus on Form: It is considered the most appropriate rationale for communicative approach. Focus on form (FonF) is defined as simultaneous attention to form and meaning (and function) in the input and output during the meaningful language use as in oral interaction (Long, 1985, 1996, 2006). As well agreed, since communicative language use prioritizes meaning processing, simultaneous attention to form and meaning, or brief shift of attention to form, occurs only from time to time when learners have problems in communication and meaning negotiation begins. In order to resolve communication breakdown, the unknown linguistic item in the input or output can be requested for clarification and negotiated for its meaning. At this moment, form-meaning mapping should occur and naturally attention to form and meaning occurs, according the Long's interaction hypothesis. Therefore, when learners use the target language, more meaning negotiation occurs than when the native speakers interact with each other due to learners' language deficiency. This meaning negotiation attracts learners' attention to the new target form that has not been learned yet for the purpose of meaning processing for communication. Communicative approach, therefore, has been more cognitively supported by Long's interaction hypothesis which tried to explain cognitive process involved in communicative language use, rather than social.

Though FonF has been originally proposed in verbal interactional setting, as it can be elicited and observed physically in meaning negotiation phenomena, it has been expanded to other modality as well including all the situations that attention to form and meaning can occur. As a result, FonF is well agreeing with noticing proposed by Schmidt (1990, 2001) and output modification proposed by Swain (1993, 1995, 2005). Noticing is defined as cognitive registration of language form in the input and output, oral/aural or written. Noticing Hypothesis says that language use provides the opportunity for noticing the form while processing the target language for meaningful use. What enables noticing varies: formal learning experience in the past, salience, high frequency in the input and etc. Finally, output hypothesis claims that output production leads to more FonF and noticing. That is, whereas input comprehension is a more meaning-dependent processing, production activates all the lexical and grammatical knowledge in order to form the meaningful sequence of language units. Often Levelt's (1989) production model has been referred to in explaining the required step of 'formulator' in speech production: Formulator should lay out the generated message using the matching lexicon into a grammatical sequence. For the purpose of producing meaningful utterances and making communication successful, learners inevitably decide the word order and other form-related issues such as pronunciation and etc.. As a result, it requires more attention to form than input comprehension according to Swain. In sum, unlike the first group of theories, these three hypotheses propose that conscious moment during language use triggers SLA. Therefore, adults who are cognitively more mature than children were often proposed to benefit more from FonF (Ellis & Sheen, 2006).

The third group of SLA theories proposes that the role of language use is for proceduralizing declarative knowledge, that is, it is for interfacing from explicit conscious to implicit unconscious stage. The skill theory says that language use is a high level practice that proceduralizes or automatizes declarative knowledge, through the time-pressed online input comprehension and output production: at first the practice is very slow because learners use their limited human attention into form and meaning alternatively, but over time through repetition, from-processing becomes fast, ultimately automatized as it is in L1 (DeKeyser, 2007).

In SLA theories, therefore, two routes of learning, explicit and implicit, compete with each other over the position of major learning mechanism of a second language. Communicative use of language, though it is a meaning-oriented type of language processing, is proposed by the three groups of SLA theories either to facilitate implicit learning driven by innate knowledge such as UG or by simple high frequency of exposure, or to facilitate converting explicitly learned knowledge into automatized implicit knowledge (Mitchell, Myles, & Marsden, 2013). On the other hand, interaction hypothesis, noticing hypothesis and output hypothesis propose that while meaning primacy in language use is preserved, additional attention to form occurs, though they did not provide further proposal regarding the next step toward the registration into long-term memory.

Except the first group that acknowledges only implicit learning, the other two groups of theories acknowledge the two routes of learning co-existing for second language learning, conscious and unconscious of the form, or explicit and implicit. If these two learning mechanisms are both playing some role to SLA, how they divide the work is an important issue. VanPatten (1990) showed in his excellent study that attention to form and attention to meaning use the same resource pool, such that simultaneous attention to both hardly occurs. Attention to form reduces attention to meaning and vice versa. Only when the form to be attended to is important to comprehension of the whole text, the attention to form did not harm attention to meaning, i.e., comprehension. This finding matches well with FonF, or noticing because they also proposed that the linguistic features that contribute significantly to meaningful communication are more likely to be noticed or attended to. Therefore, simultaneous attention to form and meaning occurs selectively and many questions are left unanswered, regarding less meaningful linguistic features.

The proposal of the sequential division of work between explicit and implicit learning is relatively clear and concrete regarding the role of each: explicit learning of declarative knowledge followed by proceduralizing of this conscious knowledge toward automatization. In order to test the simultaneous online attention to form and meaning as in FonF or noticing, or sequential attention to form for declarative knowledge and then to attention to meaning through proceduralizing the declarative knowledge, or even no explicit attention to the form that the learners are exposed to, examining attention or the level of consciousness became crucial. Whether attention to form occurs during language use and it contributes to SLA than no attention, whether and to what extent second language has been automatized can be answered only by the exact assessment of attention and awareness. That is, both process and results crucially depend on the assessment of attention to and awareness of the language form during language use.

Apart from their different positions, regarding the property of the two routes of learning, theories agree on that (1) implicit learning is less subject to individual difference because it is occurring in the unconscious level and so is uncontrollable (Hulstijn, 2005), whereas (2) explicit learning varies from person to person due to age, WM span, motivation, learning strategies and etc. (Hulstijn, 2005), and that (3) measuring learners' consciousness of the form during the language use is crucial in testing theories of implicit or explicit learning (Leow, 2000, 2015). However, (4) it is notoriously difficult to measure consciousness, attention, and noticing, through behavioral data (Leow, Johnson, & Zarate-Sandez, 2011).

Second language learners' target language use, therefore, is argued as facilitator of implicit learning leading to implicit knowledge as proposed by the input hypothesis or leading to knowledge-like behavior as proposed by the connectionism. In this group of theories, throughout the learning processes and results, learners are not aware of the language form in particular. Because it is an implicit process, without much individual difference second language is learned basically in the same learning mechanism, UG or repeated exposure, as is their first language. On the other hand, FonF position and the skill theory acknowledge the two types of learning processes: FonF position named those two as 'focus on form' and 'focus on meaning', the skill theory named them as declarative and procedural knowledge. The former position proposes the role of conscious process in language use toward learning effect, though it does not further model the ultimate result of such processes in term of knowledge type, implicit or explicit. The latter position, skill theory, clarifies that learning begins with conscious declarative knowledge and ends up with procedural knowledge. Therefore, the level of consciousness regarding the language form during language use is critical in finding the role of consciousness both in the learning process and learning outcome.

3. BEHAVIORAL AND NEURAL METHODOLOGIES

Turning to the twenty first century, one of the innovative research trends in the field may be second language processing research that examines not only the pre and posttest of language behavior but also the more delicate measurements that indicate the level of attention and awareness of the target language form during language use, and the level of automatization in the use of the target form.

Various assessments of consciousness or automatization were used as follows. Each had strengths and weaknesses.

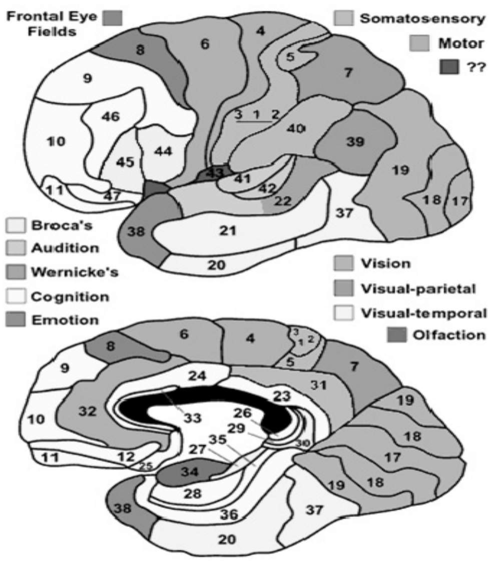
- Stimulated Recall and interview: off line assessment
- Think aloud (Leow, 2000, 2015)
- Underlining (Izumi, Bigelow, Fujiwara, & Fearnow, 1999; Izumi & Bigelow, 2000)
- Recast-uptake sequence (Gass & Mackey, 2000)
- Reaction Time (Jiang, 2007, 2012)
- Eye-tracking (Godfroid & Schmidtke, 2013; Godfroid et al., 2010, 2013)

In addition to the above methodologies, neurolinguistic approach to SLA integrated second language phenomena into biological and neurological research. Based on the earlier findings from the aphasic's brain-anatomy, the brain sectors that drive the normal fluent L1 processing of the native speakers were identified. Also the electric waves running through the brain when fluent L1 speakers process their L1 were identified as well. Those findings were used as the indices of the fully automatized language proficiency of L1, and L2 speakers' brain patterns were examined in parallel. Often L2 learners were examined for their developmental change in cross-sectional design. Other times, in order to find out the ultimate level of L2 attainment, extremely high level L2 learners' brain pattern was compared to that of native speakers, to test the hypothesis that behavioral equivalence may not guarantee the equivalence on the neurobiological level. Other than learners' L2 proficiency, several intermediate variables involving second language learning have been implemented in the neurolinguistic research.

fMRI(functional magnetic resonance imaging) locates the area of brain activated when the target stimulus is processed on the cross-sectional images of brain. Space resolution is what fMRI pursues based on Brodmann's Area, a map of human brain divided into 50 small sections. The major findings on L1 processing through fMRI are that L1 syntax is processed in Broca's area (BA44, 45), and L1 semantics is processed in Wernicke's area (BA22), as shown in Figure 1.

FIGURE 1

Brodmann- Outline with Functions (Beech, 2015)



Electric waves occurring in human brain while they are processing language stimuli are called ERPs (event related potentials). In order to measure ERPs, electrodes are attached to the scalp at 32 to 64 channels and then they are connected to the amplifier. Subjects perform language task through the monitor with the electrodes on their scalp. While processing the language stimulus, the subjects' ERPs are collected. ERPs for correct and incorrect stimuli are different either in the positive or negative voltage direction. For a semantic anomaly such as, *The pizza was too hot to cry*, the voltage is significantly different from the correct counterpart, *The pizza was too hot to eat*. At about 400 ms after the onset of the word '*cry*', this negative voltage peaks (Kutas & Hillyard, 1980), which was named N400. When syntactic anomaly occurs, positive voltage peak occurs at about 600 ms after the onset and this is called P600 (Osterhout & Holcomb, 1992). The findings on L1 processing are that L1 syntactic anomaly produces ERP patterns such as ELAN (early left anterior negativity), P600 and LAN (late anterior negativity) and that L1 semantic anomaly produces N400.

In the neurolinguistic framework normal adults' L1 processing is a model of implicit and fully automatic processing. In comparison to L1 processing, whether and how L2 processing is similar or different in brain activities is the question, depending on the various factors, e.g. age of acquisition, proficiency, type of training, degree of immersion, domain of language, types of structure, etc.

The examination of brain is not only innovative but also is considered to advance SLA research for two reasons: First, accuracy in measurement of automatization – i.e., little attention to form – has been innovatively increased. The earlier methods listed above examined learners' attention to form relying on their self-report either online, i.e., think aloud, or off-line, i.e., stimulated recall. Among the limitations of these assessments well discussed in literature, the inaccuracy in assessing the attention event is paramount and particularly online think-aloud even has the danger of misleading the learners to unnatural processing. Paying attention to the form and being aware of it are not always known to the learners to the reportable degree. fMRI and EEG enable the learners only to process the target language and assessment of the level of automatization, i.e., the opposite of attention and awarenenss, is measured intact. Therefore, the assessment itself is not relying on the learners' self-report. Underlining during reading and recast-uptake are probably better than self-report as a measurement of attention and awareness, and reaction time may be even better, though all of them are behavioral measures which may be affected by the individual factors that are irrelevant to language processing itself. However, neurobiological measurements are free of such contamination of data. Eye-movement research is another promising field of SLA study along with neurolinguistic SLA research because it is not only unobtrusive to language processing but also it opened up the new way to SLA research by adopting the accumulated findings on eye movement and human mind in psychology (Rayner, 1998). Eye fixation is well interpreted as representing attention (Godfroid et al., 2010, 2013; Rayner, 1998). Second, as eye-movement research, brain study is well connected to the already established neuroscience. That is, examining human brain while processing language enriches SLA study with general brain activities such that language can be understood in a more complete picture of human mind. In sum, thanks to the advanced technology of measuring brain activities in a unobtrusive way while it is working for language processing, automatization of language use that frees the speakers from attention to language form is accurately measured and its interpretation has become more complete in the context of neurobiological findings.

The two brain studies that compared L1 and L2, one fMRI study and one ERP study, may be exemplified as the standard for the studies that followed. Kim et al.'s study published in 1997 in Nature compared early bilinguals and late bilinguals whose L1 and L2 were Korean and English. They were all highly proficient in both languages, and generated sentences according to the picture cue by inner speech (because actual articulation produces too much noise because brain moves). They performed the same task once in their L1 and once in L2. During their performance, Broca's and Wernicke's areas were examined.

The results were that late bilinguals' centers of mass for L1 and L2 in Broca's area were far apart. The distance was statistically significant. But in Wernicke's area, the distance between the two centers of mass of L1 and L2 were close to each other. The findings suggest that late bilinguals' L2 syntactic processing is not the same as that of L1, whereas their semantic processing is the same nature in two languages. Figure 2 shows the larger distance between L1 and L2 in Broca's area for syntax processing and little distance in Wernicke's area for semantics.

FIGURE 2

Broca's Area and Wernicke's Area Activated by a Late Bilingual (Kim et al., 1997, p. 171)

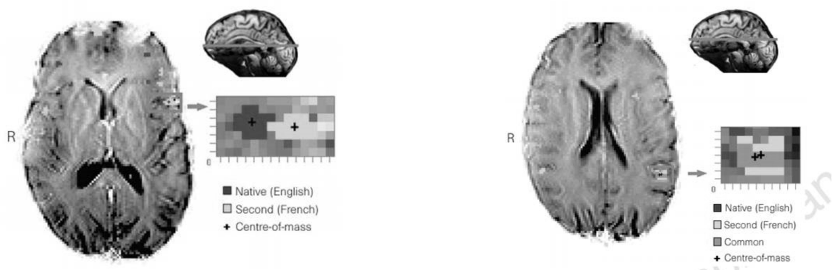
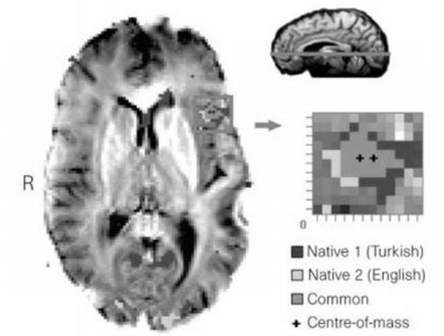


FIGURE 3

Broca's Area Activated by an Early Bilingual (Kim et al., 1997, p. 174)



In contrast, early bilinguals, (they were very early bilinguals, almost simultaneous bilinguals), processed syntax in almost the same locations within Broca's area for the two languages, as well as semantics in Wernicke's area as shown in Figure 3.

Therefore, though both early and late bilinguals are highly proficient in behavioral observation, only early bilinguals were processing L2 syntax in the same way as the native speakers, supporting the age effect on the neurobiological level.

Morgan-Short, Sanz, Steinhauer, and Ullman (2010) examined the two groups of adult L2 learners who were trained to learn an artificial language in two different ways; One group in an implicit way and the other in an explicit way until they reach a very high proficiency level so that they perform the syntactic acceptability judgment task more than 90 percent accurately. At two stages of learning, beginning stage and after they all reached very high proficient level, their ERPs were examined while they perform the syntactic acceptability judgment task.

Results showed that the explicit group when they reached high proficiency produced P600, whereas at lower level neither N400 nor P600. However, the implicit group showed P600 when they were proficient and additionally two more ERP signs of native speakers, early anterior negativity, AN, and late anterior negativity, LAN. When they were low in proficiency, they produced N400.

In short, P600 was observed in adult L2 learners when they were proficient regardless of training type. However, the more complete ERP signs of native speakers, P600, AN, LAN, were produced by implicit training only. Therefore, it is concluded that age effect was overcome by proficiency and training type, with implicit training being more effective than proficiency.

Represented by these two studies, though many other studies report the similar findings, there are converging findings on L1 and L2 processing from fMRI and ERPs. That is, lexicon is processed in the same area, producing the same ERP (N400), and syntax is processed in different areas, producing different ERP (N400, no ELAN/P600). And the difference in syntax processing is explained by age, training type, proficiency, among others, as competing factors for ultimate implicit automatized L1 level acquisition of a second language syntax.

In sum, new technical methods that use L1 speakers' brain pattern as an index of the ultimate unconscious implicit processing of a language enabled the L2 research on a new level of automatization on top of the traditional behavioral measurements. The examination of language processing on the observable language behavioral level only has been the point of debate. That is, fluent and accurate performance of the L2 speakers may process their L2 differently from their L1, though they apparently perform in the two languages equally well. Conscious processing of the language form in L2 could be as fast as L1, resulting in the same behavioral proficiency level but qualitatively it may remain as conscious processing unlike unconscious processing of their L1. Segalowitz (2003), for example, proposed that truly automatized language performance has a very small standard deviation whereas quasi-automatized language performance has a larger standard deviation even if the two types of behavior have the same average speed in performance. Segalowitz suggested the ratio between standard deviation and the mean enables the qualitative comparison of the quantitatively equivalent behaviors. Segalowitz' proposal advanced L2 research to more authentic comparison of qualitatively implicit learning or learning outcome with explicit ones. Likewise, one step further, the brain pattern may provide another level of automatized implicit processing of language.

4. A NEUROLINGUISTIC APPROACH: AN INTEGRATED MODEL

Brain pattern itself provides a new biologically integrated research into second language automatization. Further on top of it, a more composite model of second language learning was proposed by Ullman (2001) that makes an analogy to the non-language functions of brain.

Ullman's declarative and procedural model (DP Model) is based on overall brain mechanisms for non-language functions, that cover cognitive, neuroanatomical, pharmacological bases of brain system. Not surprisingly, he explains that not any one sector of brain is independently working for a particular function but that parts of brain work for multiple functions that are similar to each other. That is, Wernicke's or Broca's areas are not the only parts of brain working for only language. From the recent view of brain more as a network rather than too much localized division of work (Jeon & Friederici, 2015), DP model is not radical at all. According to the DP model, there are two memory systems relevant to language. Declarative memory is for learning, representation and use of knowledge about fact and event, such as episodic memory. It is important for arbitrary relations and is consciously available. In contrast, procedural memory is for learning new motor and cognitive skills and habits. It is important for learning sequences and it is not consciously accessible. It is an implicit mechanism.

Declarative memory is processed in medial temporal lobe including hippocampus and its activities are facilitated by acetylcholine, a neurotransmitter, by help of estrogen, a sex hormone. In contrast, procedural memory is processed in the circuit of the frontal lobe and basal ganglia, deep inside the brain. Dopamine is the neurotransmitter that activates this circuit. Regarding language domains, the functions of declarative memory are analogous to mental lexicon which is arbitrary sound-meaning parings, whereas procedural memory functions are analogous to grammar which is rule-governed combinatorial sequence of words. His lexicon-grammar distinction is tied to brain memory systems, declarative and procedural, that are known to serve other similar non-language cognitive functions in humans and other animals.

He proposed the different critical period for the development of each memory system for pharmacological reason. However, he proposed that experience and practice can overcome critical period for grammar processing. Table 1 compares the two memory systems, first in terms of non-language general functions and pharmacological factors and then in analogy to language.

TABLE 1

Declarative and Procedural Memory in DP Model

	Declarative memory	Procedural memory
General Non-language function	Learning, representation, use of knowledge about facts and events (episodic memory)	Learning new motor and cognitive skills and habits
Targets of learning	Important for learning arbitrary relations	Important for learning sequences
Consciousness	Explicit	Implicit
Areas of brain	Medial-temporal lobe (hippocampus), neocortical temporal lobe, ventro-lateral prefrontal cortex (BA 45, 47), right cerebellum	Frontal lobe (BA 44), premotor area, and ba니 ganglia, left cerebrum
Facilitating chemicals	Estrogen, Acetylcholine	Dopamine
Domain of language	Mental lexicon Arbitrary sound-meaning pairing	Grammar Rule-governed combinatorial sequences

In addition to the division of work, interactions of the two systems are found both in cooperation and competition. They are cooperative because DM acquires knowledge initially and rapidly. Then PM gradually learns the same or analogous knowledge. Time course for shift can be modulated pharmacologically. They are competitive because acetylcholine enhances DM and inhibits PM as a see-saw effect. That is, the increased functionality in one system may depress the other.

On the other hand, individual differences in DM and PM are explained as partly due to pharmacological reasons in DP model. For example, sex difference is found because women who have more estrogen throughout their lives than men are better at DM, vocabulary, verbal memory, explicit learning of grammar while males are better at grammar gradually. Age difference is found due to the early critical period for PM and later critical period for DM due to the estrogen level. Table 2 compares the different critical periods for declarative and procedural memory systems.

For declarative memory, estrogen level increases from childhood up until early adulthood in both sexes and then stays in plateau until late adulthood. From age 40, women’s estrogen level decreases significantly but male’s estrogen level decreases much

TABLE 2

Critical Period of Declarative and Procedural Memory in DP Model

Declarative memory	Age	Procedural memory
	Old adulthood age 40 and above	
*	Young adulthood	
*	Childhood	*
	Infant	*

*Colored areas indicate the critical periods for the two types of memory.

earlier. In contrast, procedural memory has much earlier critical period as in other animals. It begins at infancy and ends at childhood. Therefore, age of exposure effect differs qualitatively in childhood and adulthood: only childhood exposure activates PM system for full implicit processing. That is, implicit training in adulthood past the critical period of PM system does not activate PM system very much. Likewise the explicit training in very young childhood does not activate either DM system which has not entered its critical period yet, or PM system which does not serve explicit training efficiently. Nevertheless, Ullman (2001) proposed that experience and practice make late bilinguals overcome critical period and process grammar by procedural memory system eventually.

As a theoretical challenge to Ullman's DP Model, Clahsen and Felser (2006a, 2006b, 2006c) proposed a similar but different theory for late bilinguals. They agree on that vocabulary is learned initially and also remains in declarative system both for L1 and L2, whereas grammar is learned through a different course. Regarding the course of late L2 learners' grammar learning, they have different views. According to Ullman (2001), grammar is learned initially and remains in procedural memory system in L1, but in L2, grammar is learned at first by declarative memory system and later is shifted to procedural system like L1 when L2 proficiency is high. However, Clahsen and Felser (2006a) divided grammar into two kinds, simple local and complex nonlocal structures, and proposed that late bilinguals hardly ever shift complex structure into procedural memory system even with high proficiency. In other words, Clahsen and Felser (2006a) propose that critical period is irrecoverable for complex structures. Therefore, Ullman (2001) and Clahsen and Felser (2006a) and Felser (2006a) mostly agree with each other but they differ regarding late bilinguals' complex structure processing as summarized in Table 3..

Clahsen and Felser (2006a) distinguished full parsing from shallow parsing of structure in his Shallow Structure Hypothesis (SSH). Full parsing is a fully specified syntactic representation but shallow parsing is less detailed representation that is based on lexical-semantic, pragmatic, and other relevant nonlinguistic information. Clahsen and Felser (2006a) proposed that late-learnt L2 grammar does not provide full parsing, particularly, of non-local complex structure such as the following sentence.

The nurse who the doctor argued that the rude patient had angered is refusing to work late.

TABLE 3

Declarative and Procedural Memory for Vocabulary and Syntax in DP Model and SSH

		Vocabulary		Grammar	
Proficiency		Low	High	Low	High
DP Model	L1	Declarative	Declarative	Procedural	Procedural
	L2	Declarative	Declarative	Declarative	Procedural
Clahsen & Felser's SSH	L1	Declarative	Declarative	Procedural	Procedural (Local) Procedural (Non-local)
	L2	Declarative	Declarative	Declarative	Procedural (Local) Declarativel (Non-local)

According to SSH, when processing this sentence, natives pause at the first gap and consider *the nurse* as the filler of *who* when they encounter complementizer, *that*, according to the subjacency principle. Then they reconsider the gap after they encounter *angered* in the extraction sentence and integrate *nurse* into subcategorization of *angered*. Late bilinguals, however, do not consider the first gap filling and fail to apply subjacency principle. Instead, they are proposed to incrementally integrate thematic roles to the NPs whenever they encounter verbs. As a result, proficient late bilinguals process the same sentence in the following way: The first verb, *argued*, let the late bilinguals assign two thematic roles to the near NP and CP, agent and theme, and then the second verb, *angered,* let them assign two thematic roles to the near NP, *the rude patient* first, and then remaining far NP, *the nurse*, resulting in the correct comprehension (Clahsen & Felser, 2006b, p. 32).

a. [The nurse] who [the doctor] **argued [that**

AGENT THEME

b. [The nurse] who [the doctor] argued [that
[the rude patient] had **angered**

THEME

c. [The nurse] who [the doctor] argued [that
[the rude patient] had **angered]** is refusing to work late**.**

EXPERIENCER

Late bilinguals rely more on semantic, pragmatic information than syntactic parsing in Clahsen and Felser's SSH model. It suggests that complex syntax is hardly automatized by late L2 learners though their behavioral performance is as high as native speakers as measured by processing fluency and accuracy. Automatization of processing even underlying structure such as gap-filler structure along with subjacency principle is proposed to exist only in the native speakers.

Clahsen and Felser's (2006a) proposal does not yet seem to be readily applicable to neurolinguistic experiments such as fMRI or ERP design. Reaction time (Marinis et al., 2005; Roberts et al., 2007) or multi-modal priming studies (Felser & Roberts, 2007) have been conducted to test his proposal. Therefore, automatization, i.e., unconscious processing of language form, on the level of underlying structure, has not been assessed neurolinguistically yet, which does not imply that it is impossible, but implies that more sophisticated research design is on call.

The DP model is considered to expand the field of SLA research for fuller understanding of human mind. Focusing on the implicit automatized language ability as measured by native speakers' brain activation pattern, how L2 learners' learning stages and ultimate attainment are shaped sheds fuller insight into the field, though brain research itself does not provide visions regarding micro-level analysis of language use for effective language learning.

5. CONCLUSION

It must be meaningful to connect the new perspective from DP model with what SLA research field has discussed and found so far by how behavioral and neuro research converge and diverge. The neuro approach surprisingly converge with behavioral research in a few aspects. First, the effect of implicit learning was supported by sequence learning than by vocabulary learning as in Williams (2005) whereas effect of Focus on Form/noticing was more supported by vocabulary learning than by grammar learning (e.g. de LaFuente, 2002): it converges with neuro connection between syntax and procedural memory and between semantics and non-procedural declarative memory. Second, heritage learners' syntax is reported qualitatively different from late bilinguals: in support of early critical period for procedural memory system for structure learning. Third, the effect of FonF/noticing was larger to adult learners (Ellis & Sheen, 2005) in general and is mediated by working memory capacity for adults' grammar learning (Goo, 2010, 2012): in support of adults' strength and reliance on non-procedural and/or declarative memory system. Fourth, frequent observation of dissociation between explicit grammatical knowledge and performance converges to the neuro-based explanation that proceduralization of declarative knowledge is slow and gradual.

On the other hand, the two approaches diverge as well. First of all, neuro research is largely limited to receptive language processing. And moment-to-moment variation of consciousness level during verbal interaction, such as FonF occurring in meaning-negotiation, is far from being directly implemented into neuro experiment, yet, due to the technical issues.

Second, empirical studies often report that behaviorally native-like high proficiency in L2 syntax hardly matches with full automatized implicit knowledge in terms of brain signs. It is not clear whether it is because there is qualitative difference in processing the underlying structure as Clahsen and Felser (2006a) propose.

Third, a finer behavioral index of automatization that involves statistical notion called, Coefficient of variation (CV) (Segalowitz & Hulstijn, 2005) is a new challenge to a nuero study. Automatization defined by CV is based on the hypothesis that when performance is speeded up, variation in performance (that is, standard deviation) reduces accordingly. CV is the ratio of standard deviation to mean. The reduction of SD is of the two kinds: Coefficient of variation (CV) or relative SD, could remain unchanged while speed is up, because SD reduces in proportion to mean speed. This is a simple physical change of speed without qualitative difference. In contrast, restructuring occurs when standard deviation reduces more than proportionally to mean performance time because all controlled factors are eliminated for automatization. Therefore, coefficient of variation (CV)/relative SD decreases while speed is up. This has been proposed as a qualitative change in the processing algorithms for automatization. If neuro research is aimed at explaining behavioral data, it may have to design the research equivalent to new behavioral index such as CV as well.

In conclusion, neurolinguistic research adds depth to and enriches the behavioral research often by testing behaviorally based SLA hypotheses, though at present neurolinguistic research is restrictively applied to assessing the level of automatization, rather than to the direct measurement of attention and awareness, which is under the theoretical controversy over being a necessary process for language learning or not. The two approaches are needed to be developed in parallel interacting with each other. The behavioral research targeting language use is believed to develop for more sophistication from various perspectives, linguisitic as Clahsen and Felser's (2006a) SSH, or statistic as in CV, or communicatively oriented attention and awareness as in FonF/noticing. Interpreting ever developing and finer-tuned behavioral research also is considered to be the challenge to neurolinguistic research. Finding the more and more fine-tuned behavioral and neurophysiological correlates would bring the fuller understanding of SLA from multiple perspectives and the advancement of the field.

REFERENCES

Beech, J. (2015). *Topic 1 The study of nervous system: A brief history*. Retrieved on September, 2016, from the World Wide Web: http://slideplayer.com/slide/2427750/

Clahsen, H., & Felser, C. (2006a). How native-like is non-native language processing? *Trends in Cognitive Sciences, 10*, 564-570.

Clahsen, H., & Felser, C. (2006b). Grammatical processing in first and second language learners. *Applied Psycholinguistics, 27*, 3-42.

Clahsen, H., & Felser, C. (2006c). Continuity and shallow structures in language processing. *Applied Linguistics, 27*, 107-126.

DeKeyser, R. (2007). *Practice in a second language: Perspectives from applied linguistics and cognitive psychology.* New York, NY: Cambridge University Press.

De LaFuente, M. (2002). Negotiation and oral acquisition of L2 vocabulary: The role of input and output in the receptive and productive acquisition of words. *Studies in Second Language Acquisition, 24,* 81-112.

Ellis, N. (2002). Frequency effects in language processing: A review with implications for theories of implicit and explicit language acquisition. *Studies in Second Language Acquisition, 24,* 143-188.

Ellis, N. (2003). Constructions, chunking, and connectionism: The emergence of second language structure. In C. Doughty & M. Long (Eds.), *The handbook of second language acquisition* (pp. 63-103). Malden, MA: Blackwell Publishing.

Ellis, R., & Sheen, Y. (2006). Reexamining the role of recasts in second language acquisition. *Studies in Second Language Acquisition, 28,* 575-600.

Felser, C., & Roberts, L. (2007). Processing wh-dependencies in a second language: A cross-modal priming study. *Second Language Research, 23*(1), 9-36.

Godfroid, A., Housen, A., & Boers, F. (2010). A procedure for testing the noticing hypothesis in the context of vocabulary acquisition. In M. Puts & L. Sicola (Eds.), *Inside the learner's mind: Cognitive processing and second language acquisition* (pp. 169-197). Amsterdam, PA: John Benjamins.

Godfroid, A., Boers, F., & Housen, A. (2013). An eye for words: Gauging the role of attention in incidental L2 vocabulary acquisition by means of eye tracking. *Studies in Second Language Acquisition, 35*(3), 483-517.

Godfroid, A., & Schmidtke, J. (2013). What do eye movement tell us about awareness?: A triangulation of eye movement data, verbal reports and vocabulary learning scores. In J. Bergsleithner, S. Frota, & J. Yoshioka (Eds.), *Noticing and second language acquisition: Studies in honor of Richard Schmidt.* (pp. 183-206). Honolulu, HI: National Foreign Language Resource Center, University of Hawaii.

Gass, S. & Mackey, A. (2000). *Stimulated recall in second language research*. Mahwah, NJ: Lawrence Erlbaum.

Goo, J. (2010). Working memory and reactivity. *Language Learning, 60*, 712-752.

Goo, J. (2012). Corrective feedback and working memory capacity in interaction-driven L2 learning. *Studies in Second Language Acquisition, 34*, 445-474.

Hulstijn, J. (2005). Theoretical and empirical issues in the study of implicit and explicit second-language learning. *Studies in Second Language Acquisition, 27,* 129-140.

Izumi, S., Bigelow, M., Fujiwara, M., & Fearnow, S. (1999). Testing the output hypothesis: Effects of output on noticing and second language acquisition. *Studies in Second Language Acquisition, 21*(3), 421-451.

Izumi, S., & Bigelow, M. (2000). Does output promote noticing and second language acquisition? *TESOL Quarterly, 34*(2), 239-278.

Jeon, H., & Friederici, A. (2015). Degree of automaticity and prefrontal cortex. *Trends in Cognitive Sciences, 19*(5), 244-250.

Jiang, N. (2007). Selective interlanguage of linguistic knowledge in adult second language learning. *Language Learning, 57*(1), 1-33.

Jiang, N. (2012). *Conducting reaction time research in second language studies*. New York, NY: Routledge.

Krashen, S. (1982). *Principles and practice in second language acquisition*. Oxford: Pergamon press.

Krashen, S. (1985). *The input hypothesis*. London: Longman.

Kim, K., Relkin, N., Lee, K., & Hirsh, R. (1997). Distinct cortical areas associated with native and second languages. *Nature, 388,* 171-174.

Kutas, M., & Hillyard, S. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203-205.

Leow, R. (2000). The study of the role of awareness in foreign language behavior: Aware vs. unaware learners*. Studies in Second Language Acquisition, 22*, 557-584.

Leow, R. (2015). *Explicit learning in the L2 classroom: A student-centered approach*. New York: Routledge, Taylor, & Francis Group.

Leow, R., Johnson, E., & Zarate-Sandez, G. (2011). Getting a grip on the slippery construct of awareness: Toward a finer-grained methodological perspective. In C. Sanz & R. Leow (Eds.), *Implicit and explicit language learning: Conditions, processes, and knowledge in SLA and bilingualism* (pp. 61-72). Washington, DC: Georgetown University Press.

Levelt, W. (1989). *Speaking: From intention to articulation*. Cambridge, MA: Massachusettes Institute of Technology Press.

Long, M. (1985). Input and second language acquisition theory. In S. Gass & C. Madden (Eds.), *Input in second language acquisition* (pp. 377-393). Rowley, MA: Newbury House.

Long, M. (1990). The least a second language acquisition theory needs to explain. *TESOL Quarterly, 24,* 649-666.

Long, M. (1996). The role of the linguistic environment in second language acquisition. In W. Richie & T. Bhatia (Eds.), *Handbook of second language acquisition* (pp. 413-468). San Diego: Academic Press.

Long, M. (2006). *Problems in SLA*. Mahwah, NJ: Lawrence Erlbaum Associates.

Marinis, T., Roberts, L., Felser, C., & Clahsen, H. (2005). Gaps in second language sentence processing. *Studies in Second Language Acquisition, 27*, 53-78.

Mitchell, R., Myles, F., & Marsden, E. (2013). *Second language learning theories* (3rd ed.). London: Routledge.

Morgan-Short, K., Sanz, C., Steinhauer, K., & Ullman, M. (2010). Second language acquisition of gender agreement in explicit and implicit training conditions: An event-related potential study. *Language Learning, 60*(1), 154-193.

Osterhout, L., & Holcomb, P. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31*(6), 785-806.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*, 372-422.

Roberts, L., Marinis, T., Felser, C., & Clahsen, H. (2007). Antecedent priming at gap positions in children's sentence processing. *Journal of Psycholinguistic Research, 36*, 175-188.

Schmidt, R. (1990). The role of consciousness in second language learning. *Applied Linguistics, 11,* 129-158.

Schmidt, R. (2001). Attention. In P. Robinson (Ed.), *Cognition and second language insturction* (pp. 3-32). Cambridge, MA: Cambridge University Press.

Segalowitz, N. (2003). Automaticity in second language. In C. Doughty & M. Long (Eds.), *The handbook of second language acquisition* (pp. 382-408). Malden, MA: Blackwell.

Segalowitz, N., & Hulstijn, J. (2005). Automaticity in bilingualism and second language learning. In J. F. Kroll, & A. B. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches.* (pp. 371-388). Oxford, UK: Oxford University Press.

Swain, M. (1993). The output hypothesis: Just speaking and writing aren't enough. *The Canadian Modern Language Review, 50,* 158-164.

Swain, M. (1995). Three functions of output in second language learning. In G. Cook & B. Seidhofer (Eds.), *Principle and practice in applied linguistics* (pp. 125-144). Oxford, UK: Oxford University Press.

Swain, M. (2005). The output hypothesis: Theory and research. In E. Hinkel (Ed.), *Handbook of research in second language teaching and learning* (pp. 471-483). Mahwah, NJ: Lawrence Erlbaum Associates.

Ullman, M. (2001). The neural basis of lexicon and grammar in first and second language: The declarative/procedural model. *Bilingualism: Language and Cognition, 4,* 105-122.

VanPatten, B. (1990). Attention to form and content in the input: An experiment in consciousness. *Studies in Second Language Acquisition, 12*, 287-301.

Williams, J. (2005). Learning without awareness. *Studies in Second Language Acquisition, 27*(2), 269-304.

Applicable levels: Tertiary

Haemoon Lee
Dept. of English Language and Literature
College of Humanities, Sungkyunkwan University
3-53, Myungryun-dong, Jongro-gu, Seoul, 110-745, Korea
Phone: 02-760-0249
Email: haemoon@skku.edu

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