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What Mechanism Operates on Interlanguage Development of Procedural Knowledge?: SPM Functions

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This study explores the questions on what mechanism operates on the IL (interlanguage) developmental processes of procedural knowledge, and how procedural IL developmental sequence can be constructed. For these purposes, the present study proposes Speech Processing Mechanisms (SPM), consisting of three components, [αIFM], [βCOM], [γSCM], which can capture the degrees of constituent movements and word-order changes in a sentence. And on the SPM, this study devises a set of *developmental-stage-functions* called the *SPM functions*, that is, f (α,β,γ) = [γSCM ([αIFM]/[βCOM])*] ('*' indicates that [γSCM ([αIFM]/[βCOM])] is recursive.). Finally, this study shows that the SPM can quantify the relative procedural complexity of the processing and the construction of utterances IL learners may produce, and that the SPM functions can stagealize a procedural IL developmental sequence of 1X,... $1X^2$,... $1X^3$,... kX^n called the Procedural Developmental Sequence (PDS). Being able to explain the developmental stages of embedded clauses as well as those of non-embedded ones, the PDS can thus overcome the limitations of Pienemann and Johnston's Sequence (1987) based on Speech Processing Strategies (SPS). In conclusion, the SPM, its functions, and the PDS will be able to provide not only practical implications for language pedagogy, but also a logical explanation for what has come to be known as developmental problems to Second Language Acquisition (SLA).

I. PROCEDURAL KNOWLEDGE AND PROCEDURAL MECHANISMS

What is procedural knowledge? Since the distinction was made between *declarative* and *procedural* knowledge by Anderson (1976, 1982, 1983) in his Adaptive Control of Thought Model, a number of studies have been carried out based on these (or similar) concepts (Hulstijn & De Graaff, 1994; Levelt, 1989; Paradis, 1994; Pienemann, 1998;

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Robinson, 1996). However, up to now, few studies have made a systematic and specific definition, or even an operational one for declarative and procedural knowledge. There has been a debate in L2 literature between the interface position which insists that two types of knowledge are interfaced, and the non-interface position which insists that they are not related.

Thus, in order to reconcile the contention between interface and non-interface positions and to provide a theoretical framework for SLA research related to these two types of knowledge, the questions on what the core of declarative and procedural knowledge is and how these two types of knowledge can be defined will be first explored. In exploring them, this study focuses only on procedural knowledge, though declarative knowledge will be discussed when it is related to this study.

How can we define procedural knowledge? From a psycholinguistic perspective, if we could agree on an operational definition of procedural knowledge as executive or performing knowledge of how to process and produce language in real time, then it is necessary to find out a cognitive or procedural mechanism which governs the IL developmental sequence of procedural knowledge.

A brief review of previous studies follows on cognitive or procedural mechanisms. Bever (1970) identified a number of *processing strategies* on a cognitive basis which can account for the way native speakers process language in real time. Slobin (1973) attempted to describe the universal principles, by which children extract and segment linguistic information in order to construct a grammar of the language they are learning. Slobin (1985) finally identified a total of forty *operating principles* through his painstaking analysis of production data from many unrelated languages. Based on Slobin's operating principles, Andersen (1988) sorted out seven operating principles of L2 acquisition.

However, such principles have garnered criticisms. Dulay and Burt (1974) and Larsen-Freeman (1975) pointed out that they are not mutually exclusive and difficult to test. And Ellis (1994) also argued that there is no explanation of the principles themselves, and that only when this explanation is available will the problems concerning the number and the form of the principles be resolvable. In sum, there are problems in relying on the operating principles as a procedural mechanism to determine the IL developmental sequence of procedural knowledge, because the principles totally lack hierarchical relations among each principle, thereby not capable of capturing how they are related to each other and what weight is to be attached to them when they conflict.

Finally, Clahsen (1984), based on Bever’s strategies and Slobin’s principles, suggested Speech Processing Strategies (SPS), stated in such a way that the SPS are constraints on movement transformations, on which he and his colleagues constructed the *developmental sequence*, the core of the Multidimensional Model (Clahsen, Meisel & Pienemann, 1983; Pienemann & Johnston, 1987). However, the SPS seems to have some problems in explaining the IL development of embedded clauses because it is constructed as serial connection combinations of its components (a full discussion will be presented in the next section).

The above sketch of the research on cognitive or procedural mechanisms has led to some questions: What is the essence of procedural knowledge? What mechanism operates on the IL development of procedural knowledge? And how can a procedural IL developmental sequence be constructed?

In search of some possible answers to these questions, the present study proposes the Speech Processing Mechanisms (SPM), remotely inspired by the SPS, which can quantify the relative processing complexity of utterances produced by IL learners. And on the SPM, this study devises a set of *developmental-stage-functions* called the *SPM functions*, which can play a kind of procedural mechanism to sequence the IL developmental stages of procedural knowledge. Finally, according to the SPM functions, the study constitutes a procedural IL developmental sequence called the Procedural Developmental Sequence (PDS).

II. THE DEVELOPMENTAL SEQUENCE ON SPEECH PROCESSING STRATEGIES

In this section, the SPS and Pienemann and Johnston's Sequence of the Multidimensional Model will be examined, which are a theoretical basis of the SPM and its functions proposed by this study.

1. ZISA Project

Clahsen, Meisel and Pienemann (1983) suggested the Multidimensional Model on the basis of the ZISA (Zweitsprachenwerb Italienischer und Spanisher Arbeiter) Project which focused on how GSL (German as a Second Language) learners acquire the relatively complex word-order rules of German. The critical findings of the study are the Speech Processing Strategies (SPS) in (1) proposed by Clahsen (1984) and the Developmental Sequence in (2) based on it.

(1) SPS (Speech Processing Strategies)

(a) COS (Canonical Order Strategy): Surface strings reflect direct mapping of underlying meaning onto the syntactic form, as in the postulated NVN strategy (Bever, 1970), with movement into or out of the fixed meaning-bearing sequence blocked.

(b) IFS (Initialization/Finalization Strategy): Movements of elements to internal positions in the underlying sequences are blocked, so that [xyz] can be rearranged to become either [zxy] or [yzx], but not [yxz] or [xzy].

(c) SCS (Subordinate Clause Strategy): In subordinate clauses, permutations are avoided.

(2) The Developmental Sequence:

Ⅰ. Stage X — Canonical order: SVO
Ⅱ. Stage X+1 — Adverb preposing: ADV
Ⅲ. Stage X+2 — Verb separation: SEP
Ⅳ. Stage X+3 — Inversion: INV
Ⅴ. Stage X+4 — Verb-end: V-END

Three components of the SPS in (1) form a hierarchical structure depending on the degrees of psycholinguistic complexity, thus only after COS can first be operated, IFS can be operated, and also SCS can not be accessed until IFS can be operated. According to such hierarchical combinations of the SPS components, the five stages of the developmental sequence for word-order acquisition process of German are constituted as in (2), and the structures or rules belonging to each stage are determined sequentially. Therefore, it is possible for any learner to proceed from one stage to the next higher stage only when he or she can operate the SPS imposed on each stage regardless of age, native languages, or learning situations. From this point of view, it can be said that the developmental stages constitute an implicational scale of the SPS and cannot be *skipped* or *beaten*. From the basis of this logic, Pienemann (1985) advanced what he calls the Teachability Hypothesis, which implies that learners will be able to acquire a given structure or rule only if they are ‘ready’ for it, ‘readiness’ meaning that they had the precise processing prerequisites for learning, these prerequisites having already been developed at the previous stage.

2. The Developmental Sequence of English

Based on the Multidimensional Model, Pienemann and Johnston (1987) suggested the Developmental Sequence for English as a Second Language. The Sequence consists of five stages according to an implicational scale of the SPS. Examine each stage of the Sequence in detail.

Stage X manifests the Canonical Order Strategy ([+COS]) which is the simplest way to mark underlying grammatical and semantic relations, not allowing any movement of any element within a clause. Thus, learners can produce simple sequences of words or phrases simply focusing on the meaning or information, not on the grammatical knowledge of the elements concerned. Formulaic expressions like *I don't know*, or canonical SVO are the typical structures of this stage. Stage X+1 involves moving elements from one salient position to another salient position in a sentence, i.e., from sentence-final position to sentence-initial, and vice versa ([+IFS]), while leaving the canonical order intact ([+COS]). Like Stage X, since no grammatical knowledge for the moved elements is required, this stage is called ‘pre-syntactic’. Fronting structures such as *adv*-fronting, *do*-fronting, *wh*-fronting are the critical structures of this stage. Stage X+2 involves changing canonical order ([−COS]) by moving an internal constituent of a sentence to the salient (either initial or final) positions ([+IFS]), as in the case of Y/N-inversion *Can you play tennis?*. Since the grammatical knowledge for the moved constituents is needed, this stage can be the ‘true syntactic’. In Stage X+3, an internal constituent of a sentence moves not to a salient position, but to another internal position, as in the case of *wh*-questions *What did you do yesterday?*. To put it specifically, *what* (the object of *do*) moves to an initial position ([+IFS]), followed by *did* (=*-ed*) belonging to an internal constituent moves not to an initial but to an internal position ([−IFS]), resulting in the changes of canonical order ([−COS]). Thus, at this stage, learners have to recognize which grammatical categories the moved constituents belong to. The final stage, Stage X+4 involves identifying hierarchical structures of a sentence, i.e., a matrix and subordinate clauses, and moving constituents out of those subordinate clauses to other positions ([−SCS]) as in indirect-questions. The learners can not understand and produce these types of sentences only with matrix processability, and therefore they should be able to recognize hierarchical relations between the matrix and embedded clauses.

3. Contributions and Limitations of the SPS and the Developmental Sequence

On the examination so far, Pienemann and Johnston’s Sequence can be represented by a serial combination formula of three components of the SPS in (3).

(3) SPS = [αCOS], [βIFS], [γSCS]
(The value of variable α, β, or γ is + or −)

According to the hierarchical combinations of the values (+, −) of variables, α, β, and γ of the SPS, the Sequence consists of five implicational stages of X, X+1, X+2, X+3, and X+4. IL learners pass through from one stage to the subsequent on the Sequence only if they can operate the SPS which is imposed hierarchically on each stage. In this respect, it can be said that the SPS can function as a procedural mechanism for constructing an implicational IL developmental sequence of procedural knowledge. Thus, Pienemann and

Johnston's Sequence can be regarded as the first procedural IL developmental sequence according to a procedural mechanism. Therefore, the Sequence has its significance for SLA research in that this can provide a general explanation for what has come to be known as developmental problems: Why and how does the IL development change from stage X to stage X+n? (Flex, 1984).

However, with all its contributions to SLA, the Sequence has been constructed so sparsely that it has difficulty in explaining the developmental processes of embedded clauses in stages higher than Stage X+4. Consider the following embedded clauses.

(4) a. I know *that John loved Mary at that time.*
    b. I know the girl *whom John loved at that time.*
    c. *Who* do you think *John loved at that time*?
    d. I know *who* he thinks *has the best smile*.

Since all examples in (4) contain embedded clauses, they can be represented by [−COS], [−IFS], and [−SCS] according to the SPS in (3), and hence they are the structures belonging to Stage X+4 on the Sequence. What this implies is that the examples (4a-4d) are all on the same developmental stage, thereby assuming that their processing complexity of acquisition will also be the same. Even though all the examples of (4) have embedded clauses, there will be some differences in the degrees of procedural complexity depending on whether the embedded clause in question is an object of a matrix verb, a relative, an indirect-question, and this is compatible with our linguistic intuition. Thus, these differences should also be represented on the developmental sequence of procedural knowledge.

However, since Pienemann and Johnston's Sequence is constructed on the serial connection combinations of the SPS, it has a limitation that the developmental stages of embedded clauses in (4) cannot be sequentialized and represented any more on its sequence, even if the differences do exist in the degrees of procedural complexity among embedded or subordinate clauses. In addition, from the practical perspective, as Hudson (1993, p. 484) pointed out, Pienemann and Johnston's Sequence is so 'narrow' that it has a limitation to apply it into language teaching and language testing. In what follows a possible prescription for such limitations of the Sequence will be discussed.

III. PROCEDURAL DEVELOPMENTAL SEQUENCE ON SPEECH PROCESSING MECHANISMS

In this section, to overcome the limitations of Pienemann and Johnston's Sequence, the

Speech Processing Mechanisms and the *developmental-stage-functions* on the SPM will be proposed and discussed.

1. Speech Processing Mechanisms

As a prescription for the limitations of Pienemann and Johnston's Sequence, this study proposes the Speech Processing Mechanisms (SPM) which consist of three components (i.e., [αIFM], [βCOM], [γSCM]) derived from the Speech Processing Strategies (SPS) of Clahsen (1984), and makes an operational definition to each of three components to formalize the values of the variables α, β, and γ as seen in (5).

(5) SPM (Speech Processing Mechanisms)

(Here, α, β, and γ are the values of each variable of three components)

(a) [αIFM]: Initialization Finalization Mechanism

[αIFM] is a mechanism operating on constituent movements to realize grammatical changes and sentential forces. Hence, the variable α of [αIFM] will have a positive value ('+') if a certain constituent moves from an internal position to an external position, and vise versa, and the variable α will have a negative value ('−') if one moves from an internal position to another internal position within a sentence.

(b) [βCOM]: Canonical Order Mechanism

[βCOM] is a mechanism operating on word order changes within a sentence. Hence, the variable β of [βCOM] will have a positive value ('+') if no change takes place in canonical order [SVO(C)], and the variable β will have a negative value ('−') if any change takes place in the order as a result of the movements of any constituent.

(c) [γSCM]: Sentence Combination Mechanism

[γSCM] is a mechanism operating on an embedded clause when more than two sentences are combined to form a complex sentence. Hence, as a result of combining two sentences, the variable γ of [γSCM] will have a positive value ('+') if a certain constituent moves only within the embedded clause, and the variable γ will have a negative value ('−') if one moves to the outside of embedded clause, i.e., moves to the matrix.

In a nutshell, the SPM in (5) is a mechanism that can quantify the degrees of constituent movements and word order changes to realize the grammatical changes (e.g. modality, tense) and sentential forces (e.g. declaratives, interrogatives). First, [αIFM] in (5a) is a mechanism whose operation depends on whether or not there is a movement of constituents, and if there is, whether it is a single movement (when the grammatical change can be completed with one movement) or double movement (when the grammatical change can not be completed with one movement, another movement is induced). Second, [βCOM] in (5b) is a mechanism governing whether or not there is a word order change in a sentence as a result of operation on [αIFM]. Finally, [γSCM] in (5c) is a mechanism whose operation depends on whether or not there is a movement within an embedded clause, and if it is, whether the final destination (the landing site) of the movement is within or without the embedded clause (i.e., moves to the matrix).

Therefore, the processing complexity of utterances produced by IL learners can be quantified depending on each variable value of the SPM's three components. So, it can be argued that the SPM can play a kind of procedural mechanism governing the IL developmental sequence of procedural knowledge (Anderson, 1976). However, the SPM itself cannot determine the IL developmental stages of procedural knowledge.

2. Procedural Developmental Sequence

In order to determine the procedural developmental stages, this study devises a set of *developmental-stage-functions* called the *SPM functions*, which are formularized in a form of implicational recursive connection combinations of three components of the SPM as seen in (6), by modifying serial connection combinations of three components of the SPS.

(6) a. SPM f (α, β)=[αIFM]/[βCOM]
 b. SPM f (α, β, γ)=[γSCM ([αIFM]/[βCOM])]*]
 ('∗' indicates that [γSCM ([αIFM]/[βCOM])] is recursive. The value of variable α, β, or γ is + or −)

(6a), as serial connection combinations of [αIFM] and [βCOM] among the SPM's three components, is the SPM function of non-embedded clauses which can quantify the procedural complexity of simple or matrix clauses, and according to which the developmental sequence of simple or matrix clauses can be ordered into stages. On the other hand, (6b), as implicational recursive connection combinations of the components by inserting the serial combinations of (6a), i.e., the '[αIFM]/[βCOM],' into the implicational component of the '[γSCM[_/_]]', is the SPM function of embedded clauses which can quantify the procedural complexity of embedded clauses, and depending on which the developmental sequence of embedded clauses can be ordered into stages.

First, consider how the developmental sequence of non-embedded clauses can be stagealized. The substitution of the values ('+' or '−') of the variables α and β hierarchically for the function of non-embedded clauses (i.e., 6a) can result in four types of [αIFM]/[βCOM] combinations as seen in Table 1. Depending on these implicational values of the SPM combinations, the procedural complexity of non-embedded clauses can be quantified, and consequently the developmental stages of simple or matrix sentences can be sequentialized in the order of 1X, 2X, 3X, and 4X.

TABLE 1
Developmental Sequence for Non-embedded Sentences

SPM f (α, β) =	[α IFM]/[β COM]	Stages
If α = ・, β = +,	・/+	1X
If α = +, β = +,	+/+	2X
If α = +, β = −,	+/−	3X
If α = −, β = −,	−/−	4X

(‘ ・ ’ indicates non-application of the component in question.)

Now, examine how the developmental sequence of embedded clauses can be ordered into stages. Five types of [SCM([IFM]/[COM])] combinations can be derived from the substitution of the values of variable α, β, and γ hierarchically for the SPM function of embedded clauses (i.e., 6b) as shown in Table 2. According to these implicational values of the SPM combinations, the procedural complexity of embedded clauses can be quantified, and hence the developmental stages of embedded clauses can be sequentialized in the order of $1X^2$, $2X^2$, $3X^2$, $4X^2$, and $5X^2$.

TABLE 2
Developmental Sequence for Embedded Sentences

SPM f (α, β, γ) =	[γ SCM([α IFM]/[β COM])]	Stages
If α= ・, β= +, γ= ・,	[・ ([・ /+])]	$1X^2$
If α= +, β= +, γ= +,	[+ ([+/+])]	$2X^2$
If α= +, β= −, γ= +,	[+ ([+/−])]	$3X^2$
If α= −, β= −, γ= +,	[+ ([−/−])]	$4X^2$
If α= −, β= −, γ= −,	[− ([−/−])]	$5X^2$

(‘ ・ ’ indicates non-application of the component in question.)

Tables 1 and 2 exhibit that the values of two variables (α, β) of the SPM's two components ([αIFM]/[βCOM]) in Stages 1X to 4X are applied recursively to the implicational components of [γSCM], i.e., [αIFM]/[βCOM] in Stages $1X^2$ to $4X^2$. What this implies is that not only the developmental stages of non-embedded clauses but also those of embedded clauses can be constructed by the same mechanisms, and therefore both non-embedded and embedded clauses are in an implicational relation on the developmental sequence. On the other hand, since a complex sentence consists of a matrix and embedded clauses, the developmental stage of a complex sentence can be formalized through combining that of the matrix clause stagealized by the SPM function (6a) and those of the embedded clauses stagealized by the SPM function (6b). Thus the developmental stages of complex sentences can be represented as the form of '$k\mathrm{X}^n$+$k\mathrm{X}^{n-1}$... kX' (here, n is the number of embedded clauses).

It follows that from the psycholinguistic perspective, the SPM and its functions might play a kind of procedural mechanism role which can sequentialize procedural knowledge. In other words, the SPM which captures the degrees of constituent movements and word order changes can quantify the relative procedural complexity of constructing and processing utterances produced by IL learners. In addition, the SPM functions can sequentialize the degrees of this complexity quantified by the SPM, and therefore can construct what is called the Procedural Developmental Sequence (PDS).

IV. PROCEDURAL DEVELOPMENTAL STAGES

In this section, the concept of procedural gaps will be proposed as a kind of developmental force, and then each stage of the PDS will be elaborated according to the SPM and its functions.

1. Procedural Developmental Gaps as Procedural Developmental Force

Pienemann and Johnston (1987) did not explain explicitly *developmental force* which leads IL development of procedural knowledge from one stage to the next on the developmental sequence. By adopting the concepts of *gaps* and *driving force* proposed by Færch and Kasper (1986) and White (1987)[1], this study will suggest *procedural developmental gaps* as developmental force in order to explain how IL learners pass through each stage on the PDS. This may be related to what Vygotsky (1978) calls the *zone of proximal development*[2] from the broader perspective of general education.

IL structures (i.e., the output learners produce) will be called the *triggering force*, and

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1 Færch and Kasper (1986) suggested that only when there is a *gap* between L2 learners' output (i.e., the learners' current IL) and L2 input, and then L2 learners perceive the gap as a gap in knowledge, acquisition will take place. Similarly, White (1987) claimed that only when the input is incomprehensible rather than comprehensible, IL learners are able to pay a closer attention to its syntactic features of a sentence, and thus the *incomprehensible input* is the *driving force* that causes the grammatical changes.

2 Vygotsky (1978) stated that it [the zone of proximal development] is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (p. 86).

target language structures (i.e., the L2 input learners receive in the linguistic environment) will be called the *triggering cue*. And the gaps between the triggering force and the triggering cue will be called the *procedural developmental gaps*. Thus, it is based on the assumption that IL learners will develop from one procedural system to the subsequent in a stepwise fashion on the PDS, by inducing a clue to bridge the procedural developmental gaps through the interactions between the triggering force and the triggering cue.

2. Procedural Developmental Stages

In what follows the procedural developmental stages of non-embedded and embedded sentences will be fully specified according to the SPM functions, drawing on the procedural developmental gaps discussed above.[3]

1) Procedural Developmental Stage X

Procedural Developmental Stage X, hinging on the non-embedded SPM function $f(\alpha,\beta)$=[αIFM]/[βCOM], is subdivided into 1X, 2X, 3X, and 4X depending on the hierarchical combinations of the values of the variable α and β. The critical structures of this stage are SVO canonical structures, fronting structures, Y/N-questions, and *wh*-questions. In the following, each sub-stage of X will be examined more closely.

(1) Procedural Developmental Stage 1X

Procedural Stage 1X, as an initial state of IL development, involves the operation of SPM [· IFM]/[+COM], on which any movement or word order change is blocked in a sentence. In other words, IL learners can produce only canonical SVO structures at this stage simply by mapping their conceptual or mental structures directly onto Verb's argument structure, relying on what Bever (1970) called NVN strategies. Since they have not yet grasped the hierarchical or grammatical relations among constituents in a sentence, they can produce only some formulaic expressions (e.g., *I don't know, Wa-du-yu-do?*) and fragmental structures of the SVO (e.g., *I saw _ the zoo*) simply by imitating structures in the linguistic input.

(2) Procedural Developmental Stage 2X

Procedural Developmental Stage 2X is concerned with operating on the SPM [+IFM]/[+COM], according to which it is permitted to move an external element of the

[3] The data in the following sections is not 'real' but based on Pienemann and Johnston's Developmental Sequence (Pienemann & Johnston, 1987, pp. 82-83) and Pienemann's Processability Hierarchy (Pienenann, 1998, p. 171).

canonical SVO to other external (i.e., final or initial) positions ([+IFM]), but this movement cannot cause any change of canonical word order ([+COM]). Fronting structures such as *adv/do/wh*-fronting in English are the critical structures of this stage. Consider the following fronting sentences in (7).

(7) a. *Yesterday* [I met him].
  b. **Do* [you *met* her]?
  c. **Where* [*you are going*]?

As IL learners can perceive from the linguistic input that the examples of (7) consist of the canonical SVO and its external element which is considered as a semantic periphery, they can recognize that the external element of the canonical (i.e., a semantic periphery) can be moved from the final position to the initial position ([+IFM]) as seen in (7a) and (7c), or the new element *Do*, also considered as a kind of adjunct, can be added to the initial position ([+IFM]), by imitating 'true' Y/N-questions, as in (7b). But this movement can not cause the change of the canonical order ([+COM]). Finally, as establishing the SPM [+IFM]/[+COM], they can produce the critical structures of Stage 2X such as *adv/do/wh*-fronting.

(3) Procedural Developmental Stage 3X

In Procedural Stage 3X, the development is related to the operation on the SPM [+IFM]/[−COM], according to which it is possible to move the internal elements of canonical SVO to the final or initial position of the sentence ([+IFM]), or to insert new elements into the internal position of canonical SVO ([+IFM]), which, in turn, causes the changes of the canonical order ([−COM]). Aux-*en/-ing* (such as *be-ing*, *have/be+pp*), Y/N-inversion, and Comp-*to* (e.g. *I want to go*) are the critical structures of this stage.

Consider the developmental process of the procedural systems at this stage. While IL learners may produce ungrammatical sentences like (8a), they will be exposed to sentences like (8b) as a counterexample to (8a), which satisfies the Uniqueness Condition according to Lexical Functional Grammar.[4]

(8) a.*[He *has go*] there.
  b. [He [*has*] *gone*]] there.

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[4] The Uniqueness Condition (UC) is one of the well-formedness conditions in Lexical Functional Grammar (Kaplan & Bresnan, 1982), according to which the values attributed to a constituent must be compatible in a sentence. Thus UC filters out the ungrammatical sentences which contain conflicting values or features as in *They will went* (future ≠ past) (Pienemann, 1998, p. 96).

By recognizing the procedural gaps through the interactions between the triggering force of (8a) and the triggering cue of (8b), the learners can infer that the auxiliary *has* can be inserted into the appropriate internal position of the canonical SVO ([+IFM]), and the auxiliary has to be compatible with the lexical verb *gone* as seen in (8b). This causes, in turn, the changes of the canonical order ([−COM]). Consequently, by building up the SPM [+IFM]/[−COM], they can produce such critical structures.

Now, take a close look at the development of Y/N-questions, which can be regarded as playing a bridging role to proceed from Stage 3X to 4X. As arriving at this stage, IL learners may be in a dilemmatic situation in which they have to communicate by utilizing Y/N-questions, but they are not able to produce them because of not having yet acquired the related procedural system. Thus, in order to meet the communicative needs, they have to rely on 'pseudo' Y/N-questions (*Do*-fronting) like (9a) simply by adding *Do* to the sentence initial position. However, as the frequency of exposure to linguistic input increasing, they will have access to grammatical sentences like (9b) as positive evidence to (9a).

(9) a.*Do [$_{vp}$ you [$_{v'}$ met her]]?
b. Did [you meet_ her]?

Now, by recognizing the procedural gaps through the comparisons of IL structure (9a) and TL structure (9b), the learners are able to move the internal constituents (i.e., inflectional elements) of the structures to the initial position ([+IFM]) as seen in (9b), this causing the canonical order to change ([−COM]). Finally, they can process Y/N-questions productively thorough operating the SPM [+IFM]/[−COM].

(4) Procedural Developmental Stage 4X

Procedural Stage 4X is governed by the operation of the SPM [−IFM]/[−COM], on which it is possible to move the internal constituents of canonical SVO to another internal position ([−IFM]), thereby causing the word order to change ([−COM]). *Wh*-inversion and *Neg*-inversion are the critical structures of this stage.

While IL learners can produce Y/N-questions like (10a) through the SPM [+IFM]/[−COM] built up at the previous stage, they can not process 'true' *wh*-questions as they lack the SPM [−IFM][−COM] at this stage. Because, in such a dilemmatic situation, IL learners have to meet the communicative needs, they are forced to resort to 'interim' *wh*-questions (i.e., *wh*-fronting) like (10b). However, they will get access to grammatical sentences like (10c) as a counterexample to (10b).

(10) a. Did you do it yesterday?
b.*What you did yesterday?
c. What *did* you do(*-ed*) __ yesterday?

By recognizing procedural gaps through the interactions of the triggering force and the triggering cue, first the learners are able to move the internal constituent of the canonical order (*what*) to the initial position ([+IFM]) by relying on the *wh*-fronting mechanism (10b) available to them at this point. Next, they can induce that the internal elements (*did* =*ed*) should be moved to the internal position of the sentence ([−IFM]) by using the Y/N-inversion mechanism which has already been built up at the proceeding stage as in (10a), and these double movements invite the change of the canonical order to take place ([−COM]). Finally, by establishing the SPM [−IFM]/[−COM], they can process *wh*-questions productively.

It follows from the above explanations that it is only after IL learners arrive at Stage 4X that they can reach a critical point on IL development through building up the core procedural systems, that is, establishing the procedural sequence of the SPM [· IFM][+COM]→[+IFM][+COM]→[+IFM][−COM]→[−IFM][−COM]. Now they can proceed beyond this threshold level to the higher stages on IL development by recursively applying the core procedural systems of simple sentences to complex sentences. The IL developmental process of embedded clauses will be elaborated in the next section.

2) Procedural Developmental Stage X^2

Procedural Developmental Stage X^2, operating on the SPM function of embedded clauses *f*(α,β,γ)=[γSCM([αIFM]/[βCOM])]], is decomposed into $1X^2$, $2X^2$, $3X^2$, $4X^2$, and $5X^2$ according to the hierarchical combinations of the values of the variable α, β, and γ. In the following each sub-stage of X^2 will be examined in detail.

(1) Procedural Developmental Stage $1X^2$

In Procedural Stage $1X^2$, the development is related to the operation on the SPM [· SCM([· IFM]/[+COM])], according to which no movement or word order change is permitted within an embedded clause. At this stage, IL learners can produce the most prototypical embedded clauses simply by combining one canonical SVO to anther without any movement or word order change within an embedded clause, using *that* as a connector as seen in (11c).

(11) a. I hope.
b. John *will* marry Ann.

c. I hope **that** John *will* marry Ann.

By establishing the SPM [・SCM([・IFM]/[+COM])], in addition to the *that*-clause, the learners are able to produce other embedded clauses such as *for*-construction as in *I hope for John to marry Ann*, 2-Sub-Comp as in *I want John to marry Ann*, and Causative as in *I made him study harder*.

(2) Procedural Stage $2X^2$

In Stage $2X^2$, while IL learners can produce structures like (12) by utilizing the core procedural systems available to them, they may not produce structures like (13) as they lack the relevant procedural mechanism. However, they will be able to access these structures through the input.

(12) a. I wondered.
b. Who had loved you at that time?

(13) I wondered ***who*** *had loved you* at that time.

Recognizing the procedural gaps through the interactions between the triggering force and the triggering cue, the learners can induce that the *wh*-fronting structure (12b), in which *who* is moved to the initial position, can be combined with the canonical sentence (12a) by using *who* as a connector as seen in (13).

Substitute these movements and word order changes for the function $f(\alpha,\beta,\gamma)$= [γSCM([αIFM]/[βCOM])]]. Since *who* is moved to the sentence initial of the embedded clause, the value of the variable α is '+'; since this movement does not invite any word order change, the value of the variable β is '+'; since there is a movement (*wh*-movement) and the landing site is within the embedded clause, the value of the variable γ is '+.' Accordingly, the SPM function is represented in [+SCM([+IFM]/[+COM])], and the embedded clause of (13) is a critical structure belonging to Stage $2X^2$ (See Table 2.). On the other hand, the matrix clause *I wonder* belongs to Stage 1X because the canonical order is kept intact (See Table 1.). Thus, the complex sentence (13) can be expressed as $2X^2$+1X.

(3) Procedural Stage $3X^2$

In Procedural Stage $3X^2$, though IL learners can produce structures like (14a) and (14b) by utilizing the core procedural systems, they may not produce structures like (14c) as they lack the associated procedural mechanism. However, they will be able to access these structures through the input.

(14) a. I know **the man$_i$**

b. She will meet **him$_i$** at the party.

c. I know **the man$_i$ whom$_i$** she will meet ***t$_i$*** at the party.

Now, perceiving the processing gaps through interacting the force with the cue, the learners can infer that because of *the man* of (14a) and *him* of (14b) in an anaphoric relation (indicated as co-index *i*), *him* can be substituted by a relative pronoun *whom*, which is fronted (topicalized) to the sentence initial position, and that by adopting *whom* as a connector, the matrix (14a) and the embedded (14b) can be combined to one complex (relatives) as seen in (14c).

Substitute these for the function $f(\alpha,\beta,\gamma)$=[γSCM([αIFM]/[βCOM])]]. Since *whom* moves to the initial position, the value of the variable α is '+'. Since this movement gives rise to word order changes, the value of the variable β is '−'. And since there is a movement (*wh*-movement) and the landing site is within the embedded clause, the value of the variable γ is '+'. Accordingly, the SPM function is reduced to [+SCM ([+IFM]/[−COM]), and hence the stage of the embedded of (14c) belongs to Stage $3X^2$. On the other hand, the matrix *I know*, as explained earlier, belongs to Stage 1X. Thus, the procedural stage of the complex sentence (14c) can be represented as $3X^2$+1X.

(4) Procedural Stage $4X^2$

In Procedural Stage $4X^2$, IL learners can produce structures like (15a) and (15b) by operating on the core procedural systems available to them, whereas they may produce ungrammatical sentences like (15c) without canceling *wh*-inversion due to the absence of the related mechanism. As Pienemann (1998) pointed out, these phenomena are almost universal in IL development. However, the learners will be exposed to grammatical sentences like (15d) as positive evidence to (15c).

(15) a. *Whom does John like in the class?*

b. Do you **know** *who likes John in the class?*

c.*Do you **know** *whom John* ***does*** *like in the class?*

d. Do you **know** *whom John like**s** in the class?*

Perceiving the processing gaps through the comparisons of the triggering force and the cue, the learners come to realize that combing the root *wh*-question (15a) with the matrix question *Do you know* results in the ungrammatical sentence as seen in (15c). Thus, they can infer that when a root question becomes an embedded clause, SAI (Subject/Aux Inversion) has to be *canceled* or *reinverted*, that is, *does* should be moved back to the original position, and this movement brings about word order changes as seen in (15d).

Substitute these for the function $f(\alpha,\beta,\gamma)=[\gamma SCM([\alpha IFM]/[\beta COM])]]$. Since what Pienemann (1998) calls *cancel inversion* takes place in which *wh*-movement (*what*) induces cancel inversion to SAI (since there is a double movement), the value of the variable α is '−'. Since these movements, in turn, invite word order changes, the value of the variable β is '−'. And since the final landing site of the movements is within the embedded clause, the value of the variable γ is '+'. Consequently, the SPM function is reduced to [+SCM([−IFM]/[−COM])], and hence the embedded clause of (15d) is the structure belonging to Stage $4X^2$. On the other hand, the matrix *do you know* belongs to Stage 3X because the auxiliary *do* is moved to the initial position, and this movement causes canonical word order to change. Thus, the procedural stage of the complex sentence (15d) is $4X^2$+3X.

(5) Procedural Stage $5X^2$

In Procedural Stage $5X^2$, IL learners can produce indirect questions like (16b) by utilizing the core procedural systems of Stage $4X^2$, but they might make ungrammatical structures like (16c) simply by applying the same mechanisms as operated on (16b) directly into the construction of the sentence (16c). But they will have access to grammatical sentences like (16d) as positive evidence to (16c).

(16) a. *Whom does John like in the class?*
b. *Do you* ***know*** *whom John likes in the class?*
c.**Do you* ***think*** *whom John likes in the class?*
d. ***Whom*** *do you* ***think*** *John likes in the class?*

Now, they can induce, recognizing the procedural gaps, that in the case of the matrix clause *Do you know* as in (16b) where the matrix verb is a *non-opinion verb* which simply asks a 'Yes or No answer' of the interlocutors, there is no need to move *whom* from the initial position of the embedded clause to the initial position of the matrix clause. Whereas in the case of the matrix clause *Do you think* as in (16d) where the matrix verb is an *opinion verb* which asks 'specific opinions', not Y/N answers, the *wh*-phrase *whom* should be moved out of the embedded clause into the initial position of the matrix clause.

Substituting these for the function $f(\alpha,\beta,\gamma)=[\gamma SCM([\alpha IFM]/[\beta COM])]]$, the values of the variable α and β are the same as those of (16b) except for the variable γ which is '−' because the final landing site of the embedded constituent *whom* is not inside but outside of the embedded clause (i.e., in the matrix). Consequently, the SPM function is represented in [−SCM([−IFM]/[−COM])], and the embedded clause of (16d) is a critical structure belonging to Stage $5X^2$. As discussed above, the matrix *do you think* belongs to Stage 3X. Thus, the procedural stage of the complex sentence (16d) is $5X^2$+3X.

It can be concluded from the above discussion that just as IL learners can complete the procedural systems of simple sentences as they arrive at Procedural Stage 4X, so can they complete the template structures of embedded sentences as they reach a critical point to Procedural Stage $5X^2$.

3) Procedural Developmental Stage X^3

The developmental stages of ‘double’ complex sentences which consist of more than two embedded clauses, represented Procedural Stage X^3, can also be sequentialized by recursively applying the same SPM function as have been applied to Procedural Stage X^2. So, apart from the full discussion of Procedural Stage X^3, the movements of constituents (especially, *wh*-words) will only be mentioned briefly. Examine the degrees of the movements of constituents and the changes of word order in (17).

(17) [<u>**Who**</u> [do you guess [_ Mary thinks [_ John loves _ at the college]]]?

As can be seen in (17), *who*, which corresponds to the object of the verb *love* in the lowest embedded clause, moves first to the initial position of the lowest embedded clause (...[<u>*who*</u> John loves _ ...]]]), and then to the initial position of the higher embedded (...[<u>*who*</u> Mary thinks...]]]), and finally to the initial position of the matrix clause ([<u>*Who*</u> [do you guess...]]]). Therefore, the procedural stage of the double complex sentence (17) can be expressed as $5X^3+5X^2+3X$. This means that the stage of the lowest embedded clause is $5X^3$, the one of the higher embedded clause is $5X^2$, and the one of the matrix is 3X. The sentence (17) is the case where the number of embedded clauses are two, but in cases where the number of embedded clauses are three, four, or even *n*, the developmental stages can also be sequentialized by the recursive applications of the SPM functions.

3. Summary of Procedural Developmental Stages

To sum up, the SPM, which captures the degrees of movements and changes of word order for realizing grammatical changes and illocutionary forces, can quantify the relative procedural complexity of the construction and the processing of utterances IL learners produce. In addition, the SPM functions can not only determine an IL developmental sequence of procedural knowledge called the PDS (Procedural Developmental Sequence), but also predict critical structures and error patterns at each stage on the PDS as illustrated in Table 3.

A closer examination of Table 3 shows that inherent in the SPM functions is an implicational relation in which the higher stage on the PDS can include the SPM and the critical structures of the lower stages, but not the reverse, which means each Procedural Stage is a necessary prerequisite for the following one. As can be seen in Table 3, the values of the variable α and β of the non-embedded SPM function $f(\alpha,\beta)$=[αIFM]/[βCOM], constitute an implicational scale, depending on which the developmental stages of the simple sentences are sequentialized, and hence the stages from 1X to 4X are in an implicational relation. Also, this time the values of the variable α and β are recursively applied to the implicational component [γSCM[αIFM]/[βCOM]] of the embedded SPM function $f(\alpha,\beta,\gamma)$=[γSCM([αIFM]/[βCOM])]. Coupled with the value of the variable γ, they also constitute an implicational scale, according to which the developmental stages of embedded clauses are sequentialized, and hence the stages from $1X^2$ to $5X^2$ are also in an implicational relation. Therefore, all stages on the PDS are in an implicational relation in toto.

TABLE 3
Procedural Developmental Sequence on SPM

Stages		Procedural Developmental Sequence: SPM f (α, β)= [αIFM]/[βCOM]	SPM f (α, β, γ)= [γSCM([αIFM]/[βCOM])*]	Critical Structures	Error Patterns
Simple Sentence	1X	[・/+]	·	SVO	···
	2X	[+/+]	·	Adv/*Wh*/*Do*-fronting	···
	3X	[+/−]	·	Aux-*en*/-*ing*, Y/N-Inv, Comp-*to*	···
	4X	[−/−]	·	*Wh*-questions	···
Complex Sentence	$1X^2$	[±/±]	[・(・/+)]]	2-Sub-Comp, Dat-Mov, *that*- clause	···
	$2X^2$	[±/±]	[+ ([+/+])]	Indirect-question/Relatives (subject)	···
	$3X^2$	[±/±]	[+ ([+/−])]	Relatives(object)	···
	$4X^2$	[±/±]	[+ ([−/−])]	Indirect-question(object)	···
	$5X^2$	[±/±]	[− ([−/−])]	Long distance-questions	···
Double Complex Sentence	⋮	⋮	⋮	⋮	⋮
	kX^n	±/±	(±/±)+(±/±)+···	· · ·	···

What this implicational relation implies is that each Procedural Stage on the PDS cannot be *skipped* or *beaten*, and hence, in a sense, the PDS constitutes the predetermined shedding processes of the SPM combinations. Therefore, IL learners cannot proceed from one stage to the subsequent stage until they can process the SPM imposed on a given stage on the PDS just as a caterpillar goes through the ordained shedding process step by step and finally becomes a butterfly.

V. CONCLUSIONS AND IMPLICATIONS

The explanations and discussion so far can lead us to the questions raised in the introduction: What is the core of procedural knowledge? What mechanism operates on the development of procedural knowledge? And how can a procedural IL developmental sequence be constructed?

It follows from the above discussion that from the psycholinguistic perspective, the SPM and its functions might play a procedural mechanism role which can analyze, describe, and sequentialize procedural knowledge. In other words, the SPM that captures the degrees of constituent movements and word order changes, which can be thought of as a core of procedural knowledge, can quantify the relative procedural complexity of constructing and processing utterances produced by IL learners. In addition, the SPM functions can sequentialize the degrees of this complexity quantified by the SPM, and hence can construct what is called the PDS (Procedural Developmental Sequence). Therefore, the SPM, its functions and the PDS could not only provide a clear definition or at least, an operational one for what Anderson calls procedural knowledge as well as a theoretical framework for sequence-based SLA research, but also a reasonable explanation for what has come to be known as developmental problems to SLA.

With all such theoretical contributions to SLA, the SPM itself, as Pienemann (1998, p. 51) pointed out, can not play a "grammar" role to explain the IL development of linguistic knowledge on the PDS. For example, on Procedural Stage $2X^2$, the SPM [+SCM([+IFS]/[+COM])] is operated, which can predict critical structures such as subject indirect-questions and relatives (see Table 3). However, this SPM in itself can not explain the grammaticality inherent in such structures. From this point of view, it might be more accurate to say that the PDS represents the sequence of the SPM itself rather than that of grammatical knowledge.

A possible alternative to such a limitation of the SPM might be what is called the Modular Approach (Ellis, 1994; Gregg, 1996; Pienemann, 1998), which suggests that the PDS constructed on the procedural mechanism, i.e., the SPM, is in a complementary relation with a syntactic sequence constructed on a syntactic mechanism. Especially, considering that Gregg (1996, p. 74) once pointed out that there is a serious imbalance between SLA research on the logical problems and on the developmental problems, and that there should be an interface between these two theories, the PDS might be able to become a complementary relation with a syntactic sequence of declarative knowledge on such syntactic mechanisms as the X-bar theory and the locality condition, as in the study of Vainikka and Young-Scholten (1996, 1998). In this respect, it might be said that the PDS could show the possibility for an interface between sequence-based and UG-based SLA research.

In addition to the theoretical implications, there may be a practical implication. As discussed already, the SPM functions can construct the PDS which explains the developmental stages of embedded clauses as well as those of non-embedded ones. They can also predict critical structures and error patterns on each stage of the PDS. Thus, the PDS can go beyond the limitations of Pienemann and Johnston's Sequence based on the SPS to overcome the 'narrowness' of the applications of it to language pedagogy as pointed out by Hudson. Especially, as mentioned above, from each stage of the PDS being in an implicational relation, a motivating principle of language pedagogy, which Pienemann calls Teachability Principles, can be derived. This implies that any instruction will be beneficial if it focuses on structures or rules of the subsequent stage of IL learners' current stage on the PDS. Thus, the PDS could give an alternative to the principal questions of recent research on Form-focused Instruction: What rules, when and how to provide for IL learners? (Doughty, 1991; Doughty & Williams, 1998; Lightbown & Spada, 1990; Robinson, 1996). Specifically, an answer to *when to teach them* will be the subsequent stage of IL learners' current stage. An answer to *what rules to teach* will be the critical structures or rules of subsequent stage governed by the associated procedural mechanisms. And an answer to *how to teach them* can be obtained by utilizing the concept of the procedural developmental gaps presented by this study.

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Applicable level: all learners from children to adults

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