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Review Article

Automation of Function Assignment in the Models of Speech Production and Second Language Acquisition

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This article explores the concept of function assignment in first language (L1) and second language (L2) speech production, compares automation of function assignment in L1 and L2 speech production, pursues factors hampering automation of function assignment in L2 speech production, and discusses how to improve automation of function assignment in L2 speech production. Grammatical encoding, of which function assignment is one of the subordinate processes, is also one of the processes in L2 speech production. While function assignment in L1 speech production is mostly automatic, it demands much attentional resources and is executed under conscious supervision in L2 speech production. L2 learners' incomplete knowledge of the target language and their limited working memory resources hamper automation of function assignment in L2 speech production. Furthermore, as per generative models of learning, to improve automation of function assignment, teachers can either adopt strategies or improve instructional designs targeting this subprocess. Together, this conceptual paper gives a comprehensive overview of automation of function assignment, explores its impact on second language acquisition (SLA), and reveals that it is feasible to facilitate automation of function assignment in L2 speech production by improving instructional designs, especially the presentation methods of sentence elements.

1. Introduction

Theories and findings on speech production are highly relevant to the study of SLA [1–3]. In L2 teaching, it is an essential prerequisite to understand how a person produces speech in the target language. Knowing clearly the psychological processes involved in L2 speech production, teachers can pin down problems that learners may come across in L2 speaking while course book editors can produce more effective textbooks.

Considering the time pressure of L2 learners in carrying out all the relevant speech production processes and the contradiction between limitedness of attentional resources [4–6] and demands for attention in L2 speech production processes, especially conceptualization, formulation, and monitoring, in different task conditions [2], any approach that can improve performance efficiency or automation in L2 speech production is valuable since increased performance efficiency or automation can contribute to fluency. Currently, many approaches that can possibly improve performance efficiency in L2 speech production have been studied, such as planning [7–9] and repetition [10–12]. However, these aforementioned approaches cannot improve performance efficiency of L2 learners who perform their tasks for the first time under time pressure in various real communication situations.

Function assignment is a crucial subprocess at the linguistic level in speech production [13]. During function assignment, lexical representations are assigned to their grammatical roles or functions, such as subject, object, and predicate verb [14]. Consider, for example, the sentence "The boy likes apples." To construct such a sentence, mental

concepts for boy, apple, and like and corresponding mental lexical representations are selected. Boy is then linked to the subject function, and apple is linked to the object function. In a configurational language like English, function assignment can influence the sequencing of words in a sentence and thus serves as "an interface between lexical and syntactic processes" [15]. Besides, during this subprocess, much attentional resources may be spent in L2 speech production.

By giving a comprehensive overview of automation of function assignment in L2 speech production, this conceptual paper aims to ascertain the existence of function assignment in L2 speech production, clarify factors that hinder automation of function assignment, and explore ways to facilitate automation of function assignment in L2 speech production based on the mechanism of function assignment and generative models of learning. Many grammatical materials usually present knowledge of sentence elements in an unsystematic and dispersed way and thus may impede the automation of function assignment and increase the demand for attention in this subprocess of speech production according to cognitive load theory (CLT) [16]. Moreover, based on generative models of learning [17–20], well-designed instructional materials can prime and facilitate proper cognitive processes. Taking the knowledge of automation of function assignment in L2 speech production and CLT and pedagogic implications of generative models of learning into consideration, it is possible to improve automation of function assignment in L2 speech production by optimizing the presentation of sentence elements so as to mitigate the demand for attentional resources in function assignment in L2 speech production. Therefore, this investigation has practical implications for the presentation of sentence elements in both classrooms and grammar course books.

This paper will first introduce various L1 and L2 speech production models. Next, the difference in the level of automation of function assignment in L1 and L2 speech production will be clarified. Then, factors that may hamper automation of function assignment in L2 speech production will be discussed. Finally, the possible application of generative models of learning in the improvement of automation of function assignment will be reviewed.

2. Function Assignment in L1 and L2 Speech Production Models

Many differences exist between L1 and L2 speech production models, such as the influence of L1 on L2 [21, 22] and automation of syntactic encoding [3]. However, as a basic procedure at the syntactic level in language production, function assignment exists in both L1 speech production [14, 23, 24] and L2 speech production [25, 26]. Actually, L2 speech production model researchers generally posit the existence of a conceptualizer, a formulator that includes grammatical encoding, and an articulator in L2 speech production [25, 27–29], and they mainly have interest in topics such as whether L1 and L2 share one lexicon [30–32] or the phenomenon of code switching [33–36].

2.1. Function Assignment in L1 Speech Production Models. Although the detailed descriptions of the processes in speech production models diverge in many ways, such as whether these processes are serial or parallel in nature, there is a broad agreement on the major processes in L1 speech production models [13, 23]. Bock [23] developed a speech production model based on the consensus on the outline of the speech production and divided language production into three broad components: the message component, the grammatical component, and the phonological component. According to Bock's model [23], the first step is to clarify the speaker's intention or meaning in communication. Then, the next step is to encode the intention or meaning into preverbal speech information while the last step determines the sound structure of utterance, following the phonetic and phonological rules. The grammatical component, which is later commonly known as grammatical coding, serves as a bridge between the message component and the phonological component and is the centerpiece of speech production. Grammatical component is composed of a functional process and a positional process. The functional process determines the grammatical functions of the selected mental lexical representations while the positional process retrieves and sequences the lexical representations. The functional process can be further divided into two processes: lexical selection and function assignment. Function assignment is viewed as a crucial process in speech production since it involves assigning mental lexical representations selected in the subprocess of lexical selection to their grammatical roles or functions, such as subject, object, or predicate verb.

Based on some prominent reviews of grammatical encoding (e.g., [13, 23]), Ferreira and Slevc [14] presented "a consensus view of the general architecture" of speech production and mainly discussed the operation of grammatical encoding. In this model, the message component, grammatical component, and phonological component are named message encoding, grammatical encoding, and phonological and phonetic encoding, respectively.

As per this model, the intention or meaning of the speaker to be encoded can be further divided into semantic meaning, relational meaning, and perspective meaning. Semantic meaning refers to the semantic characteristics of the entity, state, and action expressed; relational meaning refers to the grammatical roles played by sentence elements and their relationship; perspective meaning indicates which semantic or relational aspects of an event are more or less important by distinguishing the foreground and background and the facts such as theme or comment.

According to this model, grammatical encoding is composed of two processes: a content process and a structure process. Furthermore, the structure subprocess consists of two steps: assigning grammatical functions and determining positions of constituent structures. In the process of assigning grammatical function, sentence elements, such as subject, predicate verb, the predicative, and object, will be decided based on their relational and perspective meanings which are determined in the process of message encoding. The next step is to retrieve word forms

and determine the positions of constituent structures so that a linear sentence composed of sentence elements arranged in order will be formed.

So far, it is clear that function assignment is an important subprocess in L1 speech production. Then, we need to find out whether such a process also exists in L2 speech production.

2.2. Function Assignment in L2 Speech Production Models. Fayol [37] stated that in language production, including both written and speech production, "several components and/or information processing levels" can be divided. At the conceptual level, the message to be expressed is formed. Next, at the linguistic level, the syntactic framework and lexical units are selected and arranged based on the message to be conveyed in each sentence. Finally, at the articulatory or graphic/written level, the physical production of the message is carried out.

Bot [25] made an attempt to adapt Levelt's [24] L1 speech production model for bilingual speech production and postulated that while L1 and L2 lexis are stored as one lexicon, there are different formulators for each language. It should be noted that in Levelt's [24] model, grammatical encoding, of which function assignment is one of the subordinate processes, is considered one of the two processes of the formulator. Grammatical encoding prepares a surface structure while phonological encoding generates a phonetic plan to be forwarded to the articulator for actual speech production. Bot [25] stated that "many aspects of speaking are the same for monolingual and bilingual speakers" and Bot [25] made no change to the operation of grammatical encoding in the formulator in Levelt's [24] speech production model.

Kormos [27] claimed that L1 and L2 speech production researchers "all agree that language production has four important components," including conceptualization, formulation, articulation, and self-monitoring. It should be noted that formulation encapsulates the grammatical, lexical, and phonological encoding of the message and as is mentioned before, function assignment is a subprocess of grammatical encoding.

Thus, it is fully legitimate to confirm the existence of function assignment, which is a subprocess of grammatical encoding, in L2 speech production. Furthermore, to help L2 learners overcome possible difficulties in handling function assignment, it is necessary to explore whether function assignment is carried out differently in L1 and L2 speech production.

3. Whether Function Assignment, as a Subprocess of Grammatical Encoding in L1 and L2 Speech Production, Is Automatic or Not?

Automatic information processing and controlled information processing are two dichotomies, which occupy two ends of a continuum. According to Shiffrin and Schneider [38], controlled processing has the following characteristics: (a) it is demanding great attention; (b) it is serial in nature; (c) it is easily initiated, changed, and even reversed; and (d) it is strongly limited by the short-term memory capacity. On the other hand, automatic processing has the following features: (a) it is done without attention and unconsciously; (b) it is parallel in nature; (c) it is difficult to change, to ignore, or to inhibit once acquired; and (d) it is virtually unaffected by the short-term memory capacity. As per Segalowitz [39], the characteristics of automatic processing include "significantly less efforts or attention," "relatively immune to disruption," and efficiency. For example, the driving performance of a skilled driver can be very smooth and stable and the driving itself does not requires full attention, which forms a sharp contrast with new drivers, who usually have to pay close attention to each action in order to avoid mistakes. While driving, skilled drivers can perform a parallel task, such as talking or listening to music. In other words, "as one's skill level in a domain increases, the amount of attention and effort required to perform generally appears to decrease" and the transformation from non-automatic to automatic performance appears to be typical of almost all skill acquisition, including SLA [39]. In the field of SLA, increased performance efficiency or automation can contribute to fluency.

Concerning grammatical encoding in L1 speech production, Bot [25] holds that the processing is "largely automatic" with most part of the attention being directed to conceptualizing and some attention being given to feedback mechanism while no attention being paid to the remainder functions, which include grammatical encoding. In other words, grammatical encoding is done automatically without conscious control. Kormos [3, 27] states that in L1 speech production, while message planning/conceptualization requires attention, "formulation and articulation are automatic" and done "without conscious supervision, which ensures that processing can proceed parallel and automatically." Moreover, Kormos [3] views L1 speech as a task that is "mostly effortless and fast and requires no attention on the part of the speaker and can be done parallel with other activities such as driving, washing up, and listening to music."

While L1 speakers can carry out the processes involved in the sentence formulation stage (retrieving the mental lexical items and setting up a syntactic structure) automatically without attention, it is more likely that L2 learners with limited L2 proficiency have to activate and execute their linguistic knowledge through controlled processing [40]. In other words, L2 speakers are likely to encounter problems during the sentence formulation stage, as the processes in this stage demand much working memory resource. Kormos [3] shared a similar view that unlike in L1 speech production, syntactic processing in L2 speech production often requests attentional resources.

To summarize, as a subprocess of grammatical encoding, function assignment is basically automatic in L1 speech production. By contrast, in L2 speech production, the level of automation of function assignment varies greatly depending on the level of language efficiency of L2 learners. However, even advanced L2 learners cannot achieve full automation like their L1 counterparts [3]. Therefore, to improve automation of function assignment in L2 speech production, it is necessary to explore the factors that may hinder this subprocess.

4. Factors Hampering Automation of Function Assignment in L2 Speech Production

Learners' incomplete knowledge of the target language and their limited working memory resources can hinder automation of grammatical encoding, which is a superordinate process of function assignment. Furthermore, learners' incomplete knowledge of sentence elements, which is indispensable in function assignment, can retard automation of function assignment.

L2 learners' incomplete knowledge of the target language or resource deficit as per Dörnyei and Scott [41] is one of the factors that lead to differences between L1 and L2 production [3]. To be more specific, L2 learners' incomplete knowledge of the target language can adversely affect automation of speech production.

L2 learners' language competence is rarely complete, which makes it hard for them to express their messages as planned internally. Thus, L2 learners often "have to make conscious efforts to overcome problems in communication [3]." In other words, while L1 speakers can pay no attention to processes like grammatical processing and leave such processes operate without conscious control, L2 learners have to spend much attention in carrying out such processes consciously. L2 speakers are often in the process of learning the language itself and their limited knowledge of structures of the second language can consequently adversely impact their speech production performance.

However, the attentional resources or working memory resources are rather limited for any learner. The learner's cognitive architecture is composed of sensory memory, working memory, and long-term memory [4]. Novel information captured by sensory memory will be sent to working memory when the learner pays attention to it. To-be-learned materials are processed in working memory. Working memory can only process about seven items or elements of information simultaneously [42] and for no more than a few seconds [5]; furthermore, without rehearsal, almost all information will be forgotten after about 20 seconds [6]. The "limitation of working memory in duration and capacity" should be taken into consideration as a key factor in any instructional design [4].

The incompleteness of L2 learners' knowledge of the target language can be linked to three processes in speech production: lexical, grammatical, and phonological encoding [43]. Among the three processes, grammatical encoding is of particular importance to the current research as function assignment is a subprocess of grammatical encoding.

L2 output is much slower than L1 output because L1 speech production is "largely automatic in both the formulator and the articulator" and can be processed in parallel, whereas L2 speech production cannot be completed without attention in the grammatical and phonological encoding stages and can only be processed serially [3]. In other words, the levels of automation of the formulator and the articulator only increases alongside the general proficiency of the target language of L2 learners. However, even advanced L2 learners cannot achieve full automation of the formulator and the articulator like their L1 counterparts. L2 output speed is impeded by the need of L2 learners to look for necessary linguistic resources, such as proper words and/or syntactic structures. Moreover, all such processing requires attention, a limited working memory resource. As a result, L2 learners often have difficulty in grammatical encoding under the time pressure in real-life communication. In one word, L2 output speed is impeded by L2 learners' incomplete L2 knowledge, which can cause great demand for attentional resources in L2 speech production. However, the attentional resources are rather limited for anyone. The contradiction of request for more attention in L2 speech production and the limitedness of attentional resources can only be mitigated along with the improvement in automation of speech production, especially grammatical encoding.

Thus, it is of great significance to explore theories that can provide support for the application of the knowledge of function assignment in improving automation of function assignment in L2 speech production.

5. Generative Learning and Improvement in Automation of Function Assignment

Generative learning models consider that our brain does not work passively like a computer, which stores exactly as what is presented. Instead, active cognitive processes, such as organizing, take place inside our brain. Aiming at stimulating the mental processes involved in leaning, researchers of generative learning models have designed generative learning strategies to help students to learn. Furthermore, considering the difficulty of students in organizing presented learning materials, they emphasize the importance of organization in instructional materials [17, 44].

According to Fiorella and Mayer [17], meaningful learning involves generative activities, in which learners initiate the cognitive processing during learning and actively make efforts to make sense of the presented material. Meaningful learning features "good transfer performance as well as good retention performance" and such performances are resulted from the cognitive processing rather than behavioral activities of learners during learning [45]. As Wittrock [19] puts it, the mind of us does not receive information passively. Rather, it pays attention to the presented information selectively, interprets it, and relates it with previous knowledge. Fiorella and Mayer [17] also maintain that our brain does not work like a computer, which can take in what is presented and put it into the memory exactly as presented. Instead, cognitive processing takes place in our brain. Incoming information will be interpreted, reorganized, and integrated with formerly acquired knowledge, thereby transforming the presented objective knowledge into knowledge with personal features. In one word, the learner's cognitive processing plays an essential role in generative learning.

Generative learning is different from other forms of learning, such as rote learning and associative learning. Rote learning, also called mechanical learning, refers to learning by memorizing, resulting in remembering of what is presented; associative learning, namely, learning by building and strengthening associations, leads to quick responses to familiar stimuli; by contrast, generative learning, that is,

learning by understanding, can result in meaningful learning results since it involves actively reorganizing and integrating new information with previously learned knowledge in the mind, thereby enabling learners to apply knowledge learned in this way in new situations.

Wittrock's generative model of learning [19, 20, 44] is based on the premise that learners generate perceptions and meanings that are consistent with their prior knowledge. Wittrock [44] considers that "learning is a function of the abstract and distinctive concrete associations" that the learner produces between his previous experience and the stimuli; moreover, learning with understanding is a process of generating semantic and distinctive idiosyncratic associations between stimuli and previously attained knowledge.

As per Wittrock's [19] model of generative learning, generative learning consists of four main parts: "generation, motivation, attention, and memory." Generation refers to the connections a learner forms between different parts of the presented material (i.e., internal connections) and between the presented material and learner's prior knowledge (i.e., external connections). Generation can result in both assimilative learning, that is, fitting into existing schemas, and accommodative learning, i.e., constructing new schemas. Motivation refers to learners' willingness to make efforts to understand the material. Attention means consciously applying generative processes upon the presented material and prior knowledge, and memory refers to the learner's previously acquired knowledge.

Wittrock's model of generative learning is closely linked with the select-organize-integrate (SOI) model [17, 18], a subcomponent of the cognitive theory of multimedia learning [45]. From Fiorella and Mayer's point of view, generative learning takes place when the learner starts related cognitive processing during learning, including paying attention to the presented information in a selective manner (i.e., selecting), organizing the presented material into an integrated cognitive structure in the working memory (i.e., organizing), and "integrating the cognitive structures with each other" and with previous knowledge retrieved from long-term memory (i.e., integrating) [17]. The learner's prior knowledge, including schemas, categories, models, and principles, holds an indispensable position in generative learning. Prior knowledge can help in selecting information to be processed, organizing the incoming information, and building relations with other knowledge of similar structures.

The SOI model of generative learning includes three key cognitive processes, including selecting, organizing, and integrating. Information contained in the instruction, which is first captured by the learner's eyes and ears (or other sensory organs), will be sent and stored in sensory memory briefly. If any information in sensory memory catches the learner's attention (selecting), the attended information will be sent to working memory for further processing. In working memory, the learner will mentally reorganize the selected information into coherent mental representations based on the material's underlying structures (organizing). Meanwhile, relevant prior knowledge (such as schemas, categories, or principles) will be retrieved from long-term memory and integrated with the selected information in working memory (integrating). The knowledge newly built in working memory can be stored in long-term memory and used to solve new problems that the learner may encounter in new situations.

From the above introduction of the models of generative learning, we can see that the cognitive processes of selecting, organizing, and integrating in Mayer's SOI model theory are closely related with Wittrock's concepts of attention, constructing internal connections, and establishing external connections, respectively.

The pedagogic inspirations from the generative models of learning are twofold: learning can be improved through both the instructional design approach and the learning strategies approach. The former approach attaches importance to well-designed instructional materials that can prime and facilitate proper cognitive processes while the latter approach involves acquainting students with suitable generative learning strategies so that they can initiate generative activities that can help them understand the presented material.

Taking the twofold pedagogic inspirations from the generative models of learning into consideration, the knowledge of the processes involved in speech production can also be utilized in two ways since knowledge of speech production provides a basis for considering what processes learners may focus on in a certain stage in language production and also for examining what effects strategies or instructional designs targeting a certain process can have on actual production [40].

Firstly, being aware of the pressure that L2 language production tasks can impose on attentional resources and especially of the possibility of trade-offs between accuracy and complexity when tasks are too demanding, teachers can adopt strategies, such as planning, which can "ease the pressure on the learner's limited working memory" and thus positively influence the competition between different processes of language production and trade-offs between accuracy and complexity in language production [40]. Aimed at certain processes or stages in language production, many studies have been done (see Table 1).

Secondly, by understanding the processes involved in speech production and the strain imposed on language learners in task performance, teachers can also design instructional materials that are aimed to strengthen their ability to handle certain processes in L2 speech production, including function assignment.

6. Implications

Since teachers can strengthen L2 learners' ability to deal with certain processes in L2 speech production by improving the design of instructional materials based on the generative models of learning, it is clear that to facilitate automation of function assignment in L2 speech production, it is necessary to optimize the presentation of sentence elements, the knowledge of which is indispensable in function assignment in L2 speech production. Knowledge of sentence elements, such as what can be used as subjects or objects, is necessary in function assignment in L2 speech production. Nine types of materials can be used as subjects as shown in Table 2.

Table 1: Research studies on various stages of language production.

Strategies	Targeted processes or stages in language production	Example studies and findings
Rehearsal/task repetition (providing learners with an opportunity to perform the task before the formal performance [40])	Conceptualization, formulation, and articulation in Levelt's model	First, input repetition times are of great help to the content of story retelling. In addition, with the increase of input repetition times, fluency and lexical complexity have also improved. However, there has been no improvement in language accuracy; second, the output repetition times do not contribute to the retelling of the content of the story. However, the linguistic aspects of language production, except vocabulary complexity, have all improved [46].
Strategic planning (planning before performing a task)	Conceptualization in Levelt's model	Contributes to greater fluency and syntactic complexity [47].
Unpressured within-task planning (planning while performing a task) and strategic planning	Formulation and conceptualization in Levelt's model	Unpressured within-task planning functions well in "eliciting complex, advanced structures" while strategic planning facilitates conceptualization by facilitating "the production of item-based and easy structures" [48].

Table 2: What can be used as subjects.

What can be used as subjects?		Related page numbers in *Bo Bing English Grammar* [49]
Noun		19
Pronoun	Personal pronoun	86
	Nominal possessive pronoun	95
	Demonstrative pronoun	103
	Interrogative pronoun	112–115
	Condensed conjunctive pronoun	116–117
	Indefinite pronoun	124–142
Numeral	Cardinal numeral	154
	Ordinal numeral	156
Infinitive		295–296, 304–308
Gerund		315–316, 318, 331
Nominalized past participle		354
Nominalized adjective		378–379
Preposition	Prepositional phrase	416
	Nominalized preposition	435
Nominalized adverb		435
Subjective clause		510–511

However, beginners of L2 usually only use a very few types like nouns and pronouns as the subjects in their speech production. Also, it is quite likely that such phenomenon may have something to do with the presentation of sentence elements in grammar course books. Currently, most grammar course books (e.g., [49–52]) present knowledge of sentence elements in a dispersed and unsystematic way as shown in Table 2. For example, in *Bo Bing English Grammar* [49], in order to find out "what can be used as subjects," learners have to check more than twenty places to find the answer (see Table 2). This way of presentation is not user-friendly and is not conducive to the learners' command of sentence elements.

Compared with an ideal presentation of sentence elements based on their paradigmatic and syntagmatic relations (see Figure 1), presenting sentence elements in a dispersed and unsystematic way as illustrated in Table 2 makes it very difficult to find the answer to the aforementioned question of subjects. Actually, as per cognitive load theory (CLT) [16], presenting to-be-learned materials in a dispersed and unsystematic way like the given example on subjects can inevitably increase cognitive burden or load since learners have to split their attention between so many sources of spatially separated information. In such a situation, learners need to maintain some information in working memory and meanwhile make efforts to search for the unavailable information that is also needed in cognitive processing. In other words, learners have to allocate some of the limited working memory resources to handle unnecessarily incurred cognitive load, and consequently automation is seriously hampered.

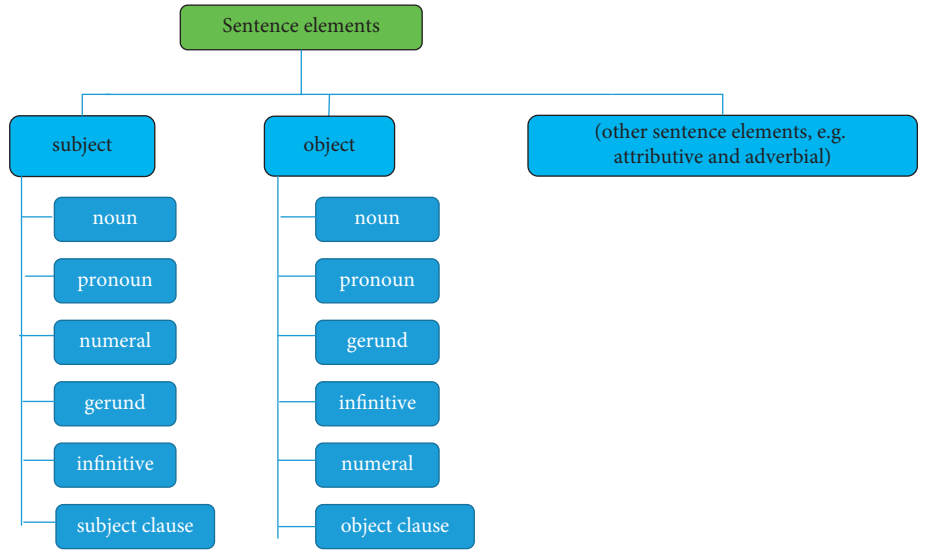

Figure 1: A schematic presenting sentence elements based on their syntagmatic relations and paradigmatic relations.

7. Conclusion

The current study has ascertained the existence of function assignment in L2 speech production, clarified the different levels of automation of function assignment in L1 and L2 speech production, explored factors that hinder automation of function assignment in L2 speech production, and revealed that it is possible to improve automation of function assignment in L2 speech production by optimizing presentation of sentence elements.

The findings of the study can serve to (a) draw attention to the application of knowledge of automation of function assignment in improving L2 learners' performance when they conduct a communication task for the first time in various real communication environments and (b) provide one of the feasible ways to improve automation of function assignment in L2 speech production by presenting sentence elements according to their paradigmatic and syntagmatic relations so as to mitigate the demand for attentional resources in function assignment. However, as a conceptual paper, the limitation of the present study is that it lacks empirical data support.

Finally, we would like to suggest that future research efforts can be made to verify the findings of the current study. To be exact, contrastive experiments need to be carried out, in which the experimental group is shown sentence elements based on the paradigmatic and syntagmatic relations and the control group is presented with sentence elements in an unsystematic way as shown, e.g., in *Bo Bing English Grammar* [49]. Such experiments can be done with the participation of learners of various ages and L2 proficiency.

Data Availability

No empirical data were used to support this study.

Conflicts of Interest

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

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