Formal Grammar Types in Language Contexts

Yvo Ad Meeres[1,*]

[1]University of Leipzig, Faculty of Mathematics and Computer Science, PO box 100 920, Leipzig 04009, Germany

Abstract

The dichotomy between generating and analytical grammars corresponds to that of production and perception. Here, we observe that different approaches to learning a language tend to concentrate on one of the two grammar types. With respect to this dichotomy, this work enumerates the preferences of different teaching approaches, including opera training, an unusual teaching context. Choosing a suitable grammar type can contribute to improving the language learning process. Indicating possible improvements with the help of the proposed formalization is our main contribution.

Although this formal dichotomy is almost trivially simple, recognizing and implementing it in language teaching would have far-reaching consequences for teaching design and for the formal and empirical analysis of processing complexity.

Keywords

formal grammar, formal language theory, language acquisition, native language, Chomsky hierarchy

1. Introduction

Language learning involves linguistic forms in two directions. In production, a speaker or writer starts with something to express and must construct a well-formed spoken or written utterance. In perception, a listener or reader is given an utterance and must recover its structure and meaning. Language teaching aims to support both directions, but the resources supplied to learners need not support them symmetrically. A rule that explains how to construct a form is directly useful for production; understanding a form that has already been encountered poses a different task.

Formal language theory provides terminology with which this difference can be made explicit. A generative grammar produces elements of a language, whereas an analytical grammar or automaton accepts or analyzes given input [1, 2]. This distinction corresponds operationally to production and perception, respectively. Generation and recognition define the same language extensionally but differ in what is given and what is sought: generation is given a grammar and seeks an element of its language, while recognition is additionally given an input and seeks a membership decision or a structural description [3]. At the semantic level, the direction is likewise reversed. Production proceeds from an intended meaning to a linguistic form, whereas perception proceeds from an observed form to possible structures and meanings. A single declarative grammar may support both operations, but this does not make their inputs, outputs, or processing direction identical.

The relevance of this distinction to language teaching is not normally stated in formal terms. Teaching materials may present rules for forming inflected words or sentences and then expect learners to use the same knowledge when hearing or reading. Vocabulary may be supplied as pairs of lemmata and meanings, although the learner encounters inflected tokens in an utterance. Moreover, the semantic information needed to understand a complete text may be distributed across a text, vocabulary lists, grammar explanations, and exercises. Describing all of these resources simply as "grammar teaching'' obscures which operation they actually support and which information the learner must still infer.

This paper therefore compares three contexts in which language is learned or trained. *Classical L2 teaching* aims at competence in both production and perception and commonly organizes material into

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*Corresponding author.

Yvo.AdMeeres@mailbox.org (Y. Ad Meeres)



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unit texts, vocabulary, grammar phenomena, and exercises. *L1 acquisition* is an implicit learning context in which children infer linguistic regularities while language and semantic information are available together in meaningful, interactive situations [4]. *Opera training* has a narrower primary goal: singers must produce the sounds of a foreign-language text accurately and expressively while understanding what they perform. Typical opera resources place phonetic, lexical, and semantic information close to the corresponding text, often in a multilayered gloss [5, 6, 7]. Opera training is therefore not presented here as an ordinary route to general L2 competence. It is a revealing comparison case because it combines highly targeted production training with unusually consolidated semantic information.

To make the comparison precise, we distinguish four language layers: pronunciation (P1), the lexicon (P2), linguistic grammar (P3), and complete input in the form of utterances or texts (P4). For each layer, we ask which generative and analytical grammars are supplied or inferred and which semantic mappings are available. The comparison is guided by two questions. First, how do classical L2 teaching, opera training, and L1 acquisition distribute grammar types and semantic information across these layers? Second, where is knowledge presented for one processing direction but expected to serve the other, and which alternative combinations become visible through the comparison?

The contribution is a formal conceptualization rather than an experimental result. First, the paper provides a formal vocabulary for describing teaching resources according to the operation they support instead of treating all grammatical knowledge as direction-neutral. This formalization also makes complexity questions accessible. If an L2 learner is given a generative grammar but must understand an observed utterance, the learner cannot simply apply the provided operation in its specified direction. Instead, the learner must use it indirectly for an analytical task, for example by generating and testing possible forms or derivations until they can be related to the input. The resulting search can be compared formally with direct analysis in terms of the required computational steps and the size of the search space. Its consequences under the real-time constraints of hearing and conversation can likewise be tested empirically through processing times and error rates. The framework thus turns the proposed mismatch between the grammar type taught and the operation required into a formal and empirically measurable hypothesis.

The take-home message of this interdisciplinary paper is deliberately simple. The elementary distinction between generation and acceptance in theoretical computer science reveals a consequential distinction when transferred to language teaching: teaching learners how to generate linguistic forms does not by itself teach them how to accept, analyze, and understand linguistic input. Making this apparently basic distinction explicit can enable fundamental changes in teaching by allowing instruction and materials to support the required processing direction directly.

Second, the paper applies this vocabulary systematically across the four language layers and the three learning contexts. Third, the comparison identifies two concrete possibilities for L2 teaching: explicitly supporting analytical grammars for hearing and reading, and presenting the semantic information for a unit text in a consolidated form similar to that used in opera training. The comparison with opera training shows that the latter organization is practicable in a real training context with demanding requirements for both pronunciation and understanding. These proposals remain hypotheses for future empirical investigation; the formal comparison itself does not establish their effectiveness.

The remainder of the paper introduces the terminology from formal language and language learning theory, defines the four layers and their semantic mappings, analyzes the three contexts layer by layer, and then compares the resulting configurations and derives the proposed directions for L2 teaching.

2. Preliminaries

This section provides definitions and background for well-known terms from the fields of formal language theory and language learning theory used throughout the paper.

Language Teaching Approaches

By *L1* we denote the native language; *L2* denotes languages learnt additionally. Learning in an L1 context is called *language acquisition*. This term refers to the process by which learners infer grammar rules implicitly rather than being taught them explicitly. *Classical language teaching* aims at complete competence in both production and perception in the L2. The significant characteristic of *language teaching in the opera* context is that its goal is not to learn the new language but to produce its foreign sounds in a beautiful, performative way while understanding its content in order to appear realistic in the opera performance.

Grammar

As usual, a *natural language* is a language spoken by humans, whereas a *(formal) language* is a possibly infinite set of elements. These elements of a language are built from a finite set called the *alphabet*. We will consider everything as a *(formal) grammar* that includes rules specifying how an element of a language is constructed from smaller elements, called *symbols*, drawn from an alphabet. This is a very wide notion of a grammar, not to be confused with the linguistic notion of grammar.[1] Following the convention in computational linguistics, we call a possibly inflected word in a natural language's sentence a *token*. A *lemma* is an abstract representation of a word in a natural language that disregards inflection and is conventionally represented by its base form. For verbs, the infinitive serves as the base form in many languages; for example, Slovak dictionaries list *robiť* rather than an inflected form such as *robím*. However, selecting a base form is language-specific and therefore not always trivial. Standard Albanian conventionally uses the first-person singular present indicative as the dictionary form, for example, *punoj* ("I work' '), rather than an infinitive [8].

A *generative grammar* generates, as its name indicates, the elements of its language L, while an *analytical grammar* accepts or rejects given input depending on whether it is part of its language L [1, 2]. The fields of automata and formal language theory mostly use an automaton as the model for an analytical grammar and a grammar as the model for a generative grammar.[2]

A recent preprint systematizes this distinction as a generation–recognition asymmetry: generation is given a grammar and seeks an element of its language, whereas recognition is given both a grammar and an input and seeks a membership decision and, in parsing, a structural description [3]. Grammar inference constitutes a third operation: examples are given and a grammar is sought, rather than a grammar being supplied for generation or recognition [12, 3]. At the semantic level, generation maps a meaning or intention to a surface form, whereas analysis maps an observed surface form to possible structures and meanings [3]. The producer therefore starts with an intended meaning, whereas the perceiver must recover possible meanings from the surface form and contextual information. A single declarative grammar can support both parsing and generation, but the two operations still differ in their inputs, outputs, and control strategies [13]. Maletti's survey of finite-state technology in natural language processing gives concrete formal realizations of several analytical tasks, including tokenization, part-of-speech tagging, and parsing, and distinguishes the models and operations used for these tasks [14]. These computational procedures are not models of human language learning, but they demonstrate that analysis can be specified and investigated separately for different linguistic tasks. Recent peer-reviewed results also illustrate how generative descriptions and analytical procedures remain distinct artifacts. An LL(k) restriction on cooperating distributed grammar systems supports a dedicated top-down parsing algorithm [15], while context-free grammars can be interpreted through tree automata to repair ambiguity and yield grammars suitable for parser generators [16]. The dependence of recognition on ambiguity and the form of the input is also visible in probabilistic membership: the problem is polynomial for unambiguous context-free languages but can already be #P-hard for unions of two linear unambiguous context-free languages [17]. Other current work establishes correspondences among register automata, logic, and expressions over data words [18] and develops automata for

[1] Throughout this paper the terms *language* and *grammar* refer to formal language and formal grammar.

[2] A wide variety of introductory textbooks for formal language and automata theory exist, such as [9, 10, 11], to name a few.

MSO over infinite trees with quantification over Borel sets of branches [19]. On the inference side, active automata learning constructs finite-state models from observations, including in the presence of noisy data [20]. These works concern formal systems; they do not themselves establish the claims about human language learning made below. At the psycholinguistic level, the P-chain framework connects production, comprehension, and acquisition by proposing that the production system supports prediction during comprehension and that prediction error drives learning [21]. This psycholinguistic proposal concerns interactions among these processes and does not by itself establish the formal distinctions or teaching claims made here.

Semantics

We define the *(formal) semantics* of an element in a language $e \in L$ as a function into the power set of a semantic domain $\mathcal{D}$: $[\![\cdot]\!] : L \to 2^{\mathcal{D}}$. The domain will be clear from the context (we could indicate it in a subscript).

As elaborated later on, our notion of formal semantics is also broader than linguistic semantics. Therefore, phonetic elements also exhibit semantic information as the well-disposed reader will see. Consequently, formal and computational notions of semantics such as `word2vec` [22], AMR [23, 24, 25], or certain graph representations [25, 26] are less broad than the above definition used throughout the comparison of the teaching approaches.

3. Grammars and Semantics of Language Layers

This section enumerates a simplified list of language layers sufficient for our purpose of comparing the teaching approaches and explains for every layer the generative and the analytical grammar as well as the semantic dimension.

In the following section we will analyze the several layers of the language concerning semantic information and grammar type used in the teaching approaches. Table 1 summarizes this analysis and therefore lists also the layers that we discuss in the current section.

The pronunciation layer (P1) includes phonetics (P1.1) and prosody (P1.2). The lexical layer (P2) comprises both base (P2.1) and inflected forms (P2.2). The grammar layer (P3), grammar in its linguistic sense, consists of morphology (P3.1) and syntax (P3.2). A whole text or conversation in a language, written or spoken, establishes the last layer (P4).

(P1) Pronunciation

A generic grammar G_{gen} for layer P1.1 of a natural language specifies movements of the human vocal tract resulting in phones. A phone p is in the generated language of G_{gen} if it is a typical sound of the natural language at hand. The corresponding G_{acc} accepts all those phones. The semantics of a phone p concerning a generative grammar specifies the movements of the vocal tract, whereas the G_{acc}'s semantics for perception is the phoneme to which the phone belongs in that specific natural language. Errors can arise in this mapping: these are classical transfer errors. Knowledge of the native language is transferred to the target language – but the transfer is incorrect. Transfer errors on vocabulary level are false friends. Analogously, for the prosodic layer P1.2 $[\![sentence]\!]$ denotes the movements for production or an IPA-transcription whereas the perception version can be given in the form of a phonological transcription.

(P2) Lexicon

The generative grammars for the lexical layers P2.1 and P2.2 enumerate all lemmata or all tokens of a natural language, respectively. The semantics for production maps a mental representation into a suitable spoken or written word in its base form (P2.1) or in its inflected form (P2.2). Vice versa, the analytical grammars map the words (lemmata for P2.1 or tokens for P2.2) to their respective meaning of

Table 1
Types of grammars available in L2, opera and L1 context

Layer	*Nr*	*Property*	**Classical L2**	**Opera L2**	**L1**
P1 Pronunciation	*P1.1*	*Phonetics*	G_{gen}	$[\![token]\!]$	$([\![lemma : noun]\!])$
	P1.2	*Prosody*	$[\![text]\!]$	$([\![sentence]\!])$	$[\![sentence]\!]$
P2 Lexicon	*P2.1*	*Lemma*	$[\![lemma]\!]$	$([\![lemma]\!])$	$[\![lemma]\!]$
	P2.2	*Inflection*	token	$[\![token]\!]$	$[\![token]\!]$
P3 Grammar	*P3.1*	*Morphology*	G_{gen}, $([\![G_{\text{gen}}]\!])$	$[\![morphem]\!]$	$[\![morphem]\!]$
	P3.2	*Syntax*	G_{gen}	$([\![sentence]\!])$	$[\![sentence]\!]$
P4 Input	*P4*	*Text*	text	$[\![text]\!]$	$[\![utterance]\!]$

each word [3]. This may be an abstract mental representation or a translation of the word into another natural language.

(P3) Grammar

A linguistic grammar for a specific natural language comprises several grammar phenomena. We consider a formal grammar in layer P3 to represent one specific grammar phenomenon. Here, a formal grammar for P3.2 itself can have a semantics since a grammar phenomenon is capable of encoding semantic information but need not. In many natural languages a sentence is turned by a grammar rule into a question. The semantics of such a grammar phenomenon G_{acc} would then be the questioning. A G_{gen} delivering all the possible questions of a certain natural language would operate on the prosodic layer P1.2 for spoken English and on the morphological layer P3.1 for many agglutinating languages. However, no grammar is necessary if a question is built on the lexical layer as it is in written language, using the punctuation symbol ? as a token at the end of every generated question. The semantics for the morphological grammar G_{acc} of a natural language maps a morpheme to its set of meanings.

(P4) Input

The semantics of an utterance $[\![utterance]\!]$ or a text $[\![text]\!]$ is, obviously, what the speaker would like to convey to the person(s) who listen(s), or what this text wants to tell the reader(s), respectively. Recently, representing the meaning of sentences $[\![sentence]\!]$ has been formalized with the help of Abstract Meaning Representation (AMR) [25] or other universal interlinguas [27]. However, these are used in research, not for language teaching.

4. Generative versus analytical grammars

This section analyzes the several layers of the language within teaching approaches. The teaching approaches differ concerning their use or ignorance of generative and analytical grammars and their semantic mappings. This analysis is summarized in Table 1 where braces indicate that the item is valid in some cases but not in general.

Grammar types in classical L2 Teaching

A classical textbook for L2 tuition comprises several chapters called units. Every unit follows the scheme: L2 text, new vocabulary, new grammar phenomena and exercises. L2 tuition is characterized

-**n**	*semantic entity*
-**n**	*genitive singular*
-**n**	*accusative singular*
-ide**n**	*genitive Plural*
-ie**n**	*genitive Plural*
-itte**n**	*genitive Plural*
-**n**	*1. person singular*
-koo/köö**n**	*3. person imperative*
-**n**	*3. person possessive suffix*
-taa/tää/tii**n**	*passive*
-**n**	*instruktive*
-**n**	*illative*
-maa/mää**n**	*illative of the infinitive III*
-mine**n**	*infinitive IV*

Figure 1: Some of the grammatical and lexical functions of the ending *-n* in Finnish lemmata

by an exhaustive use of generative grammars and low semantic information.

(P1) Pronunciation

How an L2 is pronounced concerning the phonetic layer P1.1 is often taught at the beginning of an L2 textbook. Typically, a *phoneme* and how to produce it, thus its phonetic semantics $[\![phoneme]\!]$, are described with the help of examples from the native language. This corresponds to providing a generative grammar G_{gen} on how to produce the phonemes. How to discriminate difficult foreign sounds not separated in the learner's own native language, which would result in an analytical grammar G_{acc} for perception, is of lower priority. A modern motivation for limiting the extent of the phonemic curriculum is related to the so-called intelligibility principle [28] and the notion of communicative effectiveness [29].

The prosodic layer P1.2 is rarely treated explicitly. Implicit input provides audio material for the unit text. While the textbook incorporates the *text*, the CD of audio files delivers the prosodic meaning $[\![text]\!]$. We regard the prosodic semantics of a text or utterance as the knowledge of how to use the prosodic features according to native speakers' norms.

(P2) Lexicon

Traditionally the lexicon is organized as a list of lemmata called vocabulary. The main concern is to memorize pairs of *lemma* – $[\![lemma]\!]$ by heart. Only minor grammatical or phonological content is provided in the vocabulary list. Classical L2 tuition provides tokens in chapter texts but requires the learner to derive the meaning of inflected forms, $[\![token]\!]$, from the base form $[\![lemma]\!]$ and the grammar rules G_{gen}.

(P3) Grammar

Every unit introduces a new grammar phenomenon G_{gen} and explains its semantics $[\![G_{\text{gen}}]\!]$ if the phenomenon transmits semantic information, for example, when forming the plural or using a tense in English.

The Finnish suffix *-n* serves as an example. Figure 1 lists possibilities for a token ending in *-n*. The sheer number of functions the ending *-n* fulfils is astonishing but does not even claim to be exhaustive. This does not prove the list nonsensical. Yet the opposite is the case: How should the language learner know whether or how the input may be tokenized for deriving its morphology, whether the $-n$ serves

as a morpheme in the token, whether it constitutes only the ending of a morpheme, or whether it is just plainly a phoneme in a word and no morpheme at all?

Classical L2 textbooks do not comprise analytical grammars but expect both perception and production proficiency through the study of generative grammars. A G_{acc} for Finnish tokens ending in *-n*, see again Figure 1, would certainly be helpful. A recent self-paced reading study provides an empirical parallel: structured-input training improved L2 learners' accuracy and response times when interpreting English active and passive constructions [30]. The unconscious expectation is that a G_{gen} is optimal in a situation in which a G_{acc} is needed, while the teaching approaches ignore the computational complexity of such a task.

(P4) Input

Traditionally, a unit starts with a *text* and no translation $[\![text]\!]$ is provided. The learner has to derive the meaning of the unit *text* with the help of the grammars for P2 and P3. This inference of the meaning $[\![text]\!]$ is seen as an exercise to learn the language. This didactic method is used in classes where the translation of the unit text is the most central. For instance, the language learning context of a typical Latin class shows evidence of the translation of the unit text being central in that there is little else from the categories of P1, P2, or P3 to transmit.

Most language layers are taught by providing a G_{gen}. The semantics of the language is provided almost exclusively on the lexical layer (P2.1). Merely the base form *lemma* shows up with its meaning $[\![lemma]\!]$. The inflected form *token* occurs without its semantics $[\![token]\!]$. The learner is expected to speak and write equipped only with G_{gen} and $[\![lemma]\!]$. Worse, also during perception the learner infers the meaning using G_{gen} and $[\![lemma]\!]$ even though a generative grammar processes information in the opposite direction, namely production [3]. Using a generative grammar for perception therefore means applying the wrong grammar type to the task. Instead of directly analyzing a given utterance, the learner is expected to use a production-oriented mechanism in reverse. From a computational perspective, this requirement is unnecessarily indirect and conceptually inconsistent. Hearing and reading should be accomplished with an analytical grammar just as parsers are used for this purpose in computational linguistics.

Grammar types in Opera

Opera training (see e.g. [5, 6, 7]) concentrates on semantic information and dispenses with explicit grammar presentations. Though its goal is to prepare the opera student with the proper tools and techniques to be stage ready, the necessary fluency the student demonstrates, or at least aspires to reach, mimics that of any other language learning context. It shows that the most widespread way to tackle a *hefty recitativo* (spoken / sung dialogue that moves the plot forward) is by layering text, called a *gloss*: Line 1 is the phonetic transcription; on Line 2 is the original text; Line 3 is the word-for-word translation; Line 4 is optional and either a transliteration or translation in "plain" or "modern" language. The excerpt of Mozart's *Die Zauberflöte* [5] shown in Figure 2 will serve as a running example; thus, all citations refer to this excerpt.

(P1) Pronunciation

In the context of opera training, the teaching modalities (e.g. [5]) present the phonetic layer P1 glossed in the line above the opera text in standard spelling. This phonetic transcription thus provides the semantic information for the production of layer P1. For the layer P1, the gloss provides the semantic mapping $[\![euren]\!] \mapsto$ ['ɔørən] in an adjacent row, thus making the information directly available for learning and highlighting the spoken language over the written one.

ˈlast	ˈziː	ˈdeːr	ˈpryːfuŋ	ˈfrʏçtə	ˈzeːən.	
Laß	**t**	**sie**	**der**	**Prüfung**	**Früchte**	**sehen.**
Let	them	the	trial's	fruits	see.	

(Let them see the fruits of their trials.)

ˈdɔx	ˈsɔltən	ˈziː	ˈtsuː	ˈgraːbə	ˈgeːən
Doch	**sollten**	**sie**	**zu**	**Grabe**	**gehen,**
Yet	should	they	to (their)	grave	go,

ˈzoː	ˈloːnt	ˈdeːr	ˈtuːgənt	ˈkyːnən	ˈlɑof
so	**lohnt**	**der**	**Tugend**	**kühnen**	**Lauf,**
then	reward	of the	virtue's	bold	course,

ˈneːmt	ˈziː	ˈɪn	ˈɔørən	ˈvoːnzɪts	ˈɑof
nehmt	**sie**	**in**	**euren**	**Wohnsitz**	**auf.**
receive	them	in	your	dwelling	(---)

(**auf**/**nehmen** is a separable prefix verb meaning "to recieve in a friendly manner", "to take in".)

Figure 2: Die Zauberflöte NO. 10 Aria with chorus. Sarastro

(P2) Lexicon

In the context of opera, the input text is translated word by word, so every *token* is presented along with its meaning $[\![token]\!]$, with the context taken into account. No explicit grammar G_{acc} is given; the analysis of the inflected token is done by the textbook authors; the opera student can concentrate on memorizing the opera in all its relevant aspects. A semantic function for a G_{acc} on layer P2.1, mapping into the domain $\mathcal{D}$ of German translations, would map the token *nehmen* into the set of all its possible English translations: $[\![nehmen]\!] \mapsto \{$*take*, *pick*, … $\}$. The operatic translation maps one token to exactly one translation, e.g. $[\![aufnehmen]\!] \mapsto$ *receive*. The pragmatic context (P4) and the prefix (P3.1) are considered and made transparent in this mapping: ("*receive in a friendly manner*") takes the text layer P4 into account and the morphological layer P3.1 completes *nehmen* to *aufnehmen*; this is also made transparent to the student ("*auf/nehmen is a separable prefix verb*"). Thus, vocabulary in operatic teaching is contextualized and as a consequence embeds other properties than merely those of the lexicon layer P2.

(P3) Grammar

Opera teaching exonerates the singer from inferring the opera's meaning with the help of linguistic grammars. For layer P3.1, the singer is thus exposed to a lot of input for inflected forms and their semantics $[\![token]\!]$. Additionally, for P3.2, translations at the sentence level are provided in line 4 ($[\![sentence]\!]$) if the word-by-word translation is not easily understandable, as in

$$[\![\textit{Laßt sie der}\ldots]\!] \mapsto$$

$$[\![\text{Let them see the fruits of their trials.}]\!]$$

(P4) Input

In the opera training context, the student is presented with the glossed opera text along with the semantics of all layers. If the meaning of the word-by-word translation of a sentence is not obvious, $[\![sentence]\!]$ is additionally provided. Further information is also given concerning the overall $[\![text]\!]$ present. A recent pilot study provides related empirical evidence for the role of translation in opera training: expert listeners rated singers' emotional expression and role portrayal more highly after

coaching that combined speaking the translated text in their native dialects with singing the recitative in Italian [31].

Once the singer has accomplished the core task of learning the parts of the opera for which they are responsible, they gain, in a non-inferential way, an understanding of the words, sounds, and structures. This overall understanding of the language parallels the understanding developed during L1 acquisition. It differs from the understanding typically achieved in conventional L2 learning, where learners have to infer the relevant information and retrieve it separately from grammars, vocabulary lists, and other sources. Opera students therefore attain greater language proficiency than conventional L2 learners. In opera training, this proficiency supports both performance and precision.

Operatic teaching concentrates on conveying the phonetic layer on the production side and the semantic information on the analytical side. Exhaustive linguistic grammar information is kept away from the opera singer except for rare and very specific remarks, which again serve to ease semantic understanding.

Grammar types in L1 Acquisition

Children's acquisition of a native language L1 concentrates on semantics derived from the situation.

(P1) Pronunciation

In early stages of language acquisition, children infer an analytical G_{acc} as well as a generative G_{gen} for discriminating and producing phonemes, respectively. These phonological grammars group a variety of phones humans are capable of pronouncing into a finite set of phonemes.

The young learners are presented with semantics of the phonemes, $[\![phoneme]\!]$, meaning they see lip movements and hear sounds and imitate the sounds, and do not receive anything more basic. Special emphasis is laid on the pronunciation of nouns in their base form which the parents repeat often, $[\![lemma : noun]\!]$.

(P2) Lexicon

In a very early stage of lexicon development, no reasoning to derive the semantics is expected from the child. In addition to pronouncing a *lemma:noun*, the parents point to things to indicate the lexical semantics $[\![lemma : noun]\!]$ of the noun. On the basis of these concrete objects, children start to reason about more abstract meanings of lemmata, e.g. verbs. In contrast to L2 tuition, the base form loses importance after the stage of the parents pointing to objects and calling their names.

(P3) Grammar

If specific semantic information, such as the information that something is a question, is not transported on the lexical level but via layer P3 (e.g. in Chinese or written language), the meaning of the grammar phenomenon $[\![G_{\text{gen}}]\!]$ is also derived from the situations. The time until children master full correctness in inflection takes several years. This indicates an extremely high complexity of using the linguistic grammar rules in contrast to lexicon usage. An interesting hypothesis would be to claim that building all the G_{acc} and G_{gen} correctly and optimizing them afterwards is a problem situated in the complexity class NP.

(P4) Input

The meaning $[\![utterance]\!]$ of an utterance in first language acquisition is derived from situations in a recursive manner. At the beginning stages of language acquisition, the child must begin learning the phonology (P1) and inferring the semantics of utterances with low complexity like single isolated words (P2). It combines this knowledge about the phonology $[\![phoneme]\!]$, the prosody $[\![utterance]\!]$, the lexicon $[\![lemma]\!]$ and the grammar structures G_{gen} and G_{acc} on the morphological and syntactical

levels with new reasoning about new situations in order to infer more and more semantic information about its native language. This results over time in a real-time calculation of $[\![utterance]\!]$ for a given utterance; here, real-time means that it happens at the speed of a conversation – often a problem for L2 speakers.

During L1 acquisition, children infer both analytical (G_{acc}) and generative (G_{gen}) grammars from semantic information derived from situations. In formal terms, this is grammar inference: examples and semantic information are available, but the grammars themselves are not given [12, 3]. These grammars span all language layers, from phonology to whole utterances, and are refined over several years. The resulting system supports perception and production in real time.

5. Comparison

Comparing the three teaching approaches does not only reveal differences that could have been expected due to the context in which learning takes place. The comparison also reveals unknown assumptions about the learning process. In doing so, this section contributes to a clear view of which types of grammar and semantic approaches could be fruitful in language teaching in order to ease the learning process as well as improve correctness. Often, advanced learners do not improve their skills anymore but keep making the same mistakes over and over again. Here, new methods promise a way out of this situation.

(P1) Pronunciation

Neither P1.1 nor P1.2 is a subject of study in standard L2 units, since a G_{gen} comprising the phonetic rules for producing the foreign sounds is provided at the beginning of L2 tuition and is seldom or never revisited. Discriminating sounds is expected to be accomplished using the rules for pronouncing them, thus again using the G_{gen} for P1.1.

In opera training as well, emphasis is laid upon the pronunciation of the sounds. In addition to this G_{gen}, a phonetic transcription of the written text is provided, and training of lip movements is an integral part of the courses. The opera teacher shows the correct movement and draws attention to it, whereas an L2 teacher seldom does so (hopefully when teaching the English sound “th”).

This visual information is intuitively monitored by children. They imitate their caregivers in every respect and are sensitive to phonetic input in a holistic way. In contrast to the above two teaching approaches, a child develops a G_{acc} long before training their G_{gen} for P1.

(P2) Lexicon

Classical L2 tuition provides tokens in the unit texts but requires the learner to derive the meaning of inflected forms, $[\![token]\!]$, from the base form $[\![lemma]\!]$ and the grammar rules G_{gen}. This means that in classical L2 tuition, the learner is expected

1. to generate the tokens occurring in the unit text from known and new grammar rules and known and new vocabulary:
2. to nondeterministically guess the right G_{gen} for generating a token
3. to nondeterministically guess the right *lemma* for generating a token
4. to recall the base form of this *lemma*
5. to recall $[\![lemma]\!]$ from some unit’s vocabulary list

For P2.1 only the last item is necessary. By contrast, opera students do not even need the last step, since $[\![lemma/token]\!]$ is provided along with the token or lemma itself. The only task they have to

accomplish is to read the translation.[3] This ensures constant meaningful input. Natural language acquisition also relies on constant meaningful input. The task for the child is slightly more difficult since, as discussed above, the child has to infer the semantics of new words. In contrast to an L2 learner, the child is equipped with a powerful G_{acc} and does not need to guess the right G_{gen} to produce a token in a perception setting.[4]

(P3) Grammar

Layer P3 was partly described for P2.2; see above. This description also holds for syntactical rules. Again, an L2 learner has to nondeterministically guess the right G_{gen} for perception – a kind of contradiction. But production is also difficult because the learner has to consider all grammar phenomena learned so far as possibly relevant. For writing tasks this seems feasible. Problematic is the real-time requirement in a conversation. In parallel, several G_{gen} for all relevant grammar phenomena have to be applied to generate the message the learner wishes to convey in the L2.

A child is in the same situation. However, the language acquisition process has so far ensured optimized grammars for both production and perception. Note that this optimization takes several years, so children in primary school will make frequent mistakes not only on layer P3 but also on P2. Native-like pronunciation is mastered faster. Even though children have to infer G_{gen} and G_{acc}, the constant refinement of these grammars is optimized for real-time use and leads to correctness when the children grow up.

An opera student needs neither to infer any kind of grammar nor to guess $[\![sentence]\!]$ or the like via generative grammars. Possibly, due to the semantically rich input in the form of all-encompassing information provided along with the pure opera text, opera training resembles L1 acquisition a little bit, and the opera student potentially has greater proficiency in producing correct language in real-time conversations than an L2 learner receiving conventional instruction. We do not provide evidence for the author's hypothesis here.

(P4) Input

Deriving $[\![text]\!]$ is completely up to the L2 student. The tools for accomplishing this task are, we recall, a set of generative grammars and the semantic function for P2.1 with the domain of the student's L1.

Opera students, on the contrary, can just read through both the *text* itself and $[\![text]\!]$.

Children are exposed to isolated utterances and whole conversations with a rich variety of situational information. This creates a context very different from that of studying an isolated text, as in L2 and opera contexts. Furthermore, children's L1 acquisition is inherently interactive [4]. The child can guide and elicit certain input, thereby helping the child infer the information needed to build a correct and fast L1 system.

There are several similarities between the language learning methods discussed, but, generally, after the analysis of the way grammar is conveyed some improvements are obvious.

The condensed information for an input text that opera training includes could additionally be used in normal L2 teaching. In contrast to L2 learners, small children acquiring their first language cannot use translations in order to grasp the meaning of language input. But L1 competence provides this useful mental resource: the ability to use translations to grasp meaningful input. This resource eases the language learning process. Classical L2 textbooks do use this resource only on the lexical level P2.1 for base forms of lemmata. Enriched unit texts in L2 textbooks would profit from the advantages opera training offers to date. At the lexical level, recent meta-analytic evidence provides independent support

[3] A really difficult task.
[4] A really awkward task.

for this proposal: textual glossing has a medium effect on L2 vocabulary acquisition, and this effect persists over time [32].

First and foremost, however, the comparison points to combinations of grammar types and semantic input worth trying for a better language learning experience, also in empirical studies.

6. Summary

This paper distinguishes generative grammars for production from analytical grammars for perception and applies this distinction, together with the corresponding semantic mappings, to four language layers: pronunciation, lexis, linguistic grammar, and whole utterances or texts. On this basis, it compares classical L2 teaching, opera training, and L1 acquisition.

> **Take-home message.** This interdisciplinary paper transfers an elementary distinction from theoretical computer science to language teaching: generation and acceptance are different operations. Teaching learners how to generate linguistic forms does not by itself teach them how to accept, analyze, and understand linguistic input. Making this apparently basic distinction explicit can enable fundamental changes in teaching by allowing instruction and materials to support the required processing direction directly.

The comparison indicates that classical L2 teaching mainly provides generative grammars and semantic information for lemmata. Learners are expected to use these resources not only for production but also for perception, although analytical grammars are suited to analyzing language input. During L1 acquisition, by contrast, children infer and continuously refine both grammar types from rich, meaningful, and interactive situational input. Opera training primarily teaches a generative grammar for pronunciation while providing the semantic information required to understand the complete text directly and largely avoiding linguistic grammar instruction.

The analysis suggests that L2 teaching could benefit from explicitly supporting analytical grammars for hearing and reading. It also suggests presenting unit texts together with consolidated semantic information. This conclusion is supported by the contrast with opera training, where semantic information is presented together with the text and learners are not expected to derive its meaning by applying generative grammars in reverse. The use of these combinations of grammar types and semantic input in L2 teaching remains to be investigated empirically.

Declaration on Generative AI

During the preparation of this work, the author used ChatGPT-4o (accessed via https://duck.ai) and locally installed AI systems in order to: Grammar and spelling check. After using these tools/services, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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