Grammar in 3D: on linguistic theory design
Contreras García, L.

Citation for published version (APA):
Contreras García, L. (2013). Grammar in 3D: on linguistic theory design

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
4 DIRECTIONALITY

4.1 INTRODUCTION

This chapter discusses the third and last D-feature defining the basic architectural tenets of a grammatical model, Directionality. Directionality is closely related to the first and second D-features or architectural dimensions, Distribution and Derivation as discussed in chapters 2 and 3 respectively. This chapter rounds off therefore the architectural dimensions or 3Ds with which I have set out to analyze TGG, PA and FDG. Since the term Directionality covers several related, though distinctive notions, section 4.2 introduces a brief definition of each of the notions to which the term can refer. Section 4.3 discusses the first notion of Directionality: the goal of a grammar i.e. whether that grammar is meant to either generate or analyze language. Section 4.4 discusses the second notion of Directionality: the direction of inter-level mapping processes in a given formalization of language. Section 4.5 examines the third notion of Directionality: the direction of intra-level mapping processes in a given formalization of language. Sections 4.4 and 4.5 also include a sub-section in which a fourth notion of Directionality is discussed: the direction of mapping processes involved in natural language processes and the inherent direction involved in language production and comprehension, and whether a given formalization of language mimics them or not. Section 4.6 discusses the relation between Directionality, on the one hand, and Distribution and Derivation, on the other. Section 4.7 offers a cross-model analysis of an example that reflects the models’ approach to each of the notions of Directionality discussed in the previous sections. Sections 4.8 and 4.9 round off this chapter with the conclusions as to the relation between all notions of Directionality and a summary of all aspects elaborated in the chapter.
4.2 DEFINITION

The term Directionality can refer to several related, though notably different notions regarding a linguistic model’s architecture. The notions attributed to Directionality are listed below:

(A) GOAL(S) OF THE GRAMMAR

The ability of a certain grammatical model to deal with the analysis and/or the generation of linguistic material. Directionality here refers to the potential direction(s) of the model of grammar as a goal-oriented linguistic method. Emphasis is thus paid to the goal of the grammar rather than the processes leading up to such a goal: does the grammar seek to generate, to analyze, or both to produce and analyze language? This notion is further discussed in section 4.3 below.

(B) INTER-LEVEL MAPPING DIRECTION(S)

The direction of inter-level connections due to the priority of some level(s) over other(s). The relevant questions here are: Which combinations of two levels are there? Are these connections uni-, or bi-directional? “[I]s there an inherent ‘direction’ to the relationship between two levels of description”? “[A]re the relationships among the various levels of grammatical description such that certain levels are descriptively prior to others?” (Zwicky 1972). This notion is further discussed in section 4.4 below.

(C) INTRA-LEVEL MAPPING DIRECTION(S)

The direction of the formalism within the internal structure of levels from bigger to smaller units of analysis – known as a top-down approach – or from smaller to greater units – known as a
bottom-up approach. This notion is further discussed in section 4.5 below.

(D) INTER- AND INTRA-LEVEL MAPPING DIRECTION(S) AS A MIRROR OF SPEECH PROCESSES

The extent to which a grammatical model’s inter- and intra-level Directionality mimics processes involved in real-time language use (language comprehension and production) and in natural language parsing algorithms. This section is further discussed in sections 4.4.3 and 4.5.3.

4.3 GOAL(S) OF THE GRAMMAR

This notion of Directionality (also in (A) in 4.2 above) refers to the ability of a grammatical model to deal with the analysis/parsing\(^{25}\) and/or the generation/production of linguistic material. This notion of Directionality refers to the potential direction(s) of the linguistic method, i.e. what it is designed for. A linguistic model theoretically has three formal choices: a) it is designed in order to generate linguistic material; b) it is designed in order to analyze linguistic material; c) it is designed in order to both generate and analyze linguistic material. Such choices lead in turn to three various types of grammars: a) uni-directional grammars for generation purposes; b) uni-directional grammars for analysis purposes; c) bi-directional grammars for both generation and analysis purposes. Note that the fact that a model of grammar produces and/or analyzes language does not necessarily imply that it mimics natural language production and/or analysis. Directionality is here not conceived as a top-down vs. bottom-up or as a from-left-to-right vs. from-righ-to-

\(^{25}\) Parsing is used in this chapter with two different meanings. Sometimes it refers to analysis (vs. generation as in this case) and sometimes it refers to any mapping mechanism, irrespective of whether the mapping is done for processes that mimic the analysis or the generation of language.
left notion but rather as departing from language and producing abstract representations (in which case it is a uni-directional model for language analysis), as departing from abstract representations and producing actual language (in which case it is a uni-directional model for language generation), or as performing both tasks (in which case it is a bi-directional model for language analysis and generation).

A main distinction is thus drawn between uni- and bi-directional grammars. A bi-directional grammar formalism is "an implementation formalism capable of producing grammars usable in both analysis and generation" (Newman 1990a: 1). Such an implementation is formally reversible. Note that a grammar that generates is a grammar that can reconstruct the steps/constraints/mechanisms by which language is produced, thus being able to reproduce the generation of language: “Since the parser ‘knows’ the productions of the language, its job is then defined as that of selecting which productions had to have applied to generate a particular input string . . . The parser must reconstruct the derivational history of a string from context” (Longley & Stark 2001: 18). From this perspective, TGG, PA and FDG attempt to reproduce the way in which language is generated.

Note that bi-directional grammars are usually used for machine translation purposes and normally consist of a pseudo-linguistic grammar that behaves as the bridge between a source and a target language. (28) below briefly illustrates a bi-directional model that translates by departing from the source language (SL), creating an inter-lingua (language-independent) abstract representation and translating this into the target language (TL) or vice versa.

(28) SL <-> abstract representation, inter-lingua <-> TL

Note that, for translation purposes, it is only logical to create a bi-directional grammar used for both generation and analysis instead of a bi-directional, non-reversible grammar, since there
seem to be shared preferences between analysis and generation. Such is the case of a an initial NP subject, since a grammar that generates language will always tend to position a subject NP in the initial slot, and a grammar that analyzes language will always tend to identify an initial NP as the subject (see De Kok, Plank & Van Noord 2011). However, “in many cases some elements of the specifications are direction-unique” (Newman 1990a: 1), “some rules that simplify the grammar can be used for either analysis or generation, but not both” (Gates et al 1989: 53) or adaptations are needed according to whether one deals with generation or analysis. Such is the case of raising vs. non-raising constructions, the expression of an indirect object with or without preposition, and the various possible orderings of complements, whereby decisions that are necessary for generation are not necessary for analysis (Newman 1990b: 148). These three cases are illustrated in (29), (30) and (31) below. Note that the different syntactic constellations do not necessarily lead to different interpretations. This is why a grammar for production purposes would have to make a choice as to which structure to use in production, though a grammar for interpretation purposes would not necessarily be confronted with such a decision in the analysis, for both options in each pair in (29), (30) and (31) mean the same. Bi-directional grammars are thus economical in that there is no need to write separate grammars for generation and analysis, although they may add problems as to e.g. rule ordering (see Gates et al 1989: 53).

(29) They are believed to be gods vs. It is believed that they are gods.

(30) I handed him the essay vs. I handed the essay to him.

(31) I travel from Spain to Holland vs. I travel to Holland from Spain.
4.4  INTER-LEVEL MAPPING DIRECTION(S)

4.4.1  INTRODUCTION

This second notion of Directionality (introduced in (B) in 4.2 above) refers to the direction that inter-level interfaces take. This notion is thus related to a model’s strata and the way in which these interact and, therefore, it is also related to the dimensions of Distribution and Derivation. Directionality in the sense discussed here refers to “the direction in which linguistic rules map structures through a grammatical system” (Eliasson 1978: 50). For Eliasson, two facts have given rise to an increased interest in the concept of Directionality: a more exact definition of linguistic levels and the birth (and consciousness) of multi-layered grammars. The relation between the concept of level, on the one hand, and that of Directionality, on the other, is clear: the direction of mapping takes place between two clearly defined levels or strata of representation. If these are not clearly defined (if there are no clearly defined source and target points), the direction of mappings between them cannot be determined.

Note that this notion differs from the directionality of language generation or processing as presented in 4.3 above. Rather than referring to the goal of grammar (does the grammar attempt to produce and/or analyze language), this notion of Directionality refers to the architecture of the model itself and its inter-level interfaces. The directionality of a model in this sense thus refers to the descriptive priority of certain levels upon others (Zwicky 1972). This notion also differs from that introduced in 4.2 (C) to be further discussed in section 4.5, where intra-level interfaces and the algorithmic way in which these take place are at stake. Finally, this notion of Directionality can be analyzed together with that introduced in 4.2 (D), in that a model’s inter-level Directionality may or may not mimic that involved in natural language processes. Such mimicking processes are discussed in 4.4.3 below.
4.4.2 INTER-LEVEL DIRECTIONALITY AND THE MODELS

Since this notion of Directionality is strongly related to a model’s architecture, it applies differently to TGG, PA and FDG. In TGG, the syntactic level has descriptive priority over the semantic and phonological levels. This is illustrated in Figure 42 below by the fact that arrows depart from the syntactic into the semantic and phonological levels but not vice versa. This descriptive priority of the syntactic level leads to a uni-directional (and not bi-directional) model of grammar. This is of course closely related to the derivational character of the model, since a determined order in the description of levels implies a representational dependence of derived levels upon the deriving level and this, in turn, means that the all-first source level, syntax, needs to be representationally responsible for the semantic and phonological levels of representation. This is why the syntactic level, being representationally responsible for the semantic one, now includes a sub-level of representation that mimics the semantic level (Logical Form) such that inter-level correspondences can be maintained and the semantic level can be said to be born from the syntactic one. Note, however, that Derivation and Directionality (as treated in this section) are two different concepts: while Directionality merely points at the descriptive relation between levels of representation, Derivation is the consequence of Directionality plus other factors, notably the pre-determined, sequenced order of steps of mappings.

Figure 43 below offers a different case-scenario for PA, since no level takes descriptive priority over the others. This is clear from the fact that all levels are connected in pairs, and that arrows are bi-directional. This means that mappings can take place from and into any level of description. The model makes thus use of all potential interface resources and is all-directional (or non-directional, in that no specific direction is needed for all mapping processes). Note that the relation between the different levels in PA is not that of “a sequenced derivation, since
structures in different components often stand in a many-to-
many relation” and that, therefore, “a parallel derivation has no
notion of logical sequence, as is essential in a syntactocentric
derivation” (Jackendoff 2010a: 4-5). This means that PA shows
no pre-determined Directionality among levels or, in other
words, that all directions are theoretically possible. This is so
since “phonology, syntax, and semantics are equally generative.
Syntax is thus only one of several parallel sources of
grammatical organization. The generative components
communicate with each other through ‘interface’ components”
(Jackendoff 2002: XIV-XV) that determine the model’s
Directionality.

Finally, as illustrated in Figure 44 below, FDG is a uni-
directional model. This is clear from the fact that formulation
(“meaning”) takes place before encoding and that, within the
former, interpersonal precedes representational formulation and,
within the latter, morpho-syntactic precedes phonological
encoding.26 From a theoretical point of view, some potential
interface processes are being left out (bottom-up processes
between non-successive levels of representation). Note also that
Figure 44 below could be represented as from-left-to-right
(meaning -> syntax -> sound), top-down or bottom-up, as long
as the source and target points of the arrows remain the same.

Figure 42. Inter-level Directionality in TGG27

26 Note however that interpersonal and representational formulation could
take place in parallel, and that bottom-up feedback between successive levels
of representation is allowed (see Hengeveld & Smit 2009).
27 For comparison purposes, the levels of “sound”, “syntax” and “meaning”
will be distinguished for all three models.
This sub-notion of Directionality related to inter-level mapping processes and real-time processes refers to the model’s capacity (or attempt at attaining such a capacity) to mirror the direction involved in the actual generation and/or production of language in the direction formalized between the levels “sound”, “syntax” and “meaning” in a given grammatical model. Note that this notion differs from that presented in 4.3 above. While the notion discussed here (and in 4.5.3) refers to the extent to which a model of language is able to mimic the production and/or analysis of language, the one discussed in 4.2 refers to the production and/or analysis of language as the very goal for creating the grammatical model. A comparison between the formalism and the generally postulated real-time processes taking place in language production and analysis is enlightening as to whether there is an assumed difference between the object and the method of study. Jackendoff (fc.) illustrates this difference by comparing the directionality of language perception (from sound to meaning, via syntax) and language production (from meaning to sound, via syntax) with that
involved in the directionality of derivations within a model. The Directionality involved in language comprehension and production is illustrated in Figures 45 and 46.

**Figure 45. Directionality in language comprehension**

![Diagram of sound, syntax, and meaning in language comprehension]

**Figure 46. Directionality in language production**

![Diagram of sound, syntax, and meaning in language production]

Figure 47 below shows the difference between the postulated inter-level Directionality in speech comprehension and speech production, on the one hand, and TGG, on the other. Note that Directionality in TGG contrasts with that of speech comprehension and speech production, since neither sound nor meaning appear as the source or target levels of linguistic computation. Syntax in the model is not the intermediate step between sound and meaning, but rather the source level from which both sound and meaning are born -a ‘syntactocentric’ perspective (see Jackendoff 2002, Culicover & Jackendoff 2005). This implies that Directionality in TGG contrasts with both language processing and production.

Figure 48 below shows a different case-scenario for PA. In this case, PA shows an all-to-all Directionality in that all levels are inter-connected in all directions. The default-case scenario that takes place in language processing (from sound to meaning, via syntax) as well as in language production (from meaning to sound, via syntax) is only implicit by the fact that syntax is formalized in between phonology (which normally appears on the left side) and semantics (which normally appears
on the right side). Both real-time “directions” involved in language processes thus seem to be superposed in the formalism (as the bi-headed arrows between sound-syntax and syntax-meaning show). The direct connection between phonology and semantics would explain cases in which no elaborate syntax is required. For Jackendoff (2010a: 5) “PA itself is nondirectional, but its constraints can be implemented in an order suited to particular processing tasks”. This implies that all interface options are allowed for (therefore all bi-directional processes are made explicit in the visual formalism), and a particular order can be chosen according to the model’s goal at a particular time and for a particular task. Some authors consider the coherence of a model’s direction with that in which language processes are supposed to take place in language production and comprehension as a methodological advantage:

“A speaker starts with meaning, processes what he wants to say through syntax and phonology (though with multiple feedback loops) until noises emerge. The hearer starts with the noises and processes it in reverse. Of course the classical syntacto-centric model, where everything begins with syntax, was not supposed to be a performance model, but all else being equal, a model that conforms to the way language is really used should be welcomed over one that does not” (Burling 2003: 1).

Finally, observe Figure 49 below for an illustration of inter-level Directionality in FDG compared to that involved in speech processes. It is clear from the picture that FDG is consistent with language production (from meaning – pragmatics, semantics- to sound, via morpho-syntax), with which the model welcomes, though it does not exclusively accept, parallelisms. Thus, FDG “clearly mimics the sequence found in production. Despite this seductive analogy between the architecture of FDG and the processes of speech production, it is important to emphasize [...] that FDG is a ‘model of encoded intentions and conceptualizations’ rather than, as in Levelt’s ‘blueprint for the speaker (Levelt 1989: 8 ff.), a model of
language production” (Hengeveld & Mackenzie 2008: 2). Note that, theoretically speaking, FDG “could in principle be turned on its head to account for the parsing of utterances. It is clear that listeners analyze phonetic input into phonological representations, which are subsequently grouped into morpho-syntactic constituents, from which meaningful representations are then constructed” (ibid 2008: 2). Such an approach would of course be coherent with language comprehension instead of with language production. Note that, although FDG tries to reflect psycholinguistic processes involved in speech production, it is not a model of the speaker (ibid: 2). Note also that such a formalization from the speaker’s intention down to articulation is formalized in a top-down fashion within the model following Levelt (1989: 9). This, however, is but a conventional graphic representation of the process going from intention to meaning, to morphosyntax, to phonology and down to articulation. Note that the top-down representation does not make any difference as to the Directionality of the model (it could be represented bottom-up, or left-to-right, or right-to-left) as long as the beginning and end points remain the same.

**Figure 47. Inter-level Directionality in TGG and in speech processes**

*Postulated Directionality in speech comprehension*

```
SOUND ——— SYNTAX ——— MEANING
```

*Postulated Directionality in speech production*

```
SOUND ←—— SYNTAX ——— MEANING
```

*Inter-level Directionality in GG*

```
SOUND ——— SYNTAX ——— MEANING
```
Figure 48. Inter-level Directionality in PA and in speech processes

Postulated Directionality in speech comprehension

Postulated Directionality in speech production

Inter-level Directionality in PA

Figure 49. Inter-level Directionality in FDG and in speech processes

Postulated Directionality in speech comprehension

Postulated Directionality in speech production

Inter-level Directionality in FDG
4.5 INTRA-LEVEL MAPPING DIRECTION(S)

4.5.1 INTRODUCTION

In section 4.3, Directionality was defined as the direction that the goal of the grammar takes: does it seek to generate language (departing from abstract representations) or to analyze language (into abstract representations)? In section 4.4, Directionality was analyzed as the direction in which mapping processes take place between the various levels of a model of grammar. In this sense, it is the various levels or components of a grammar that are at stake, and Directionality refers to the Direction in which interfaces are applied (from which into which levels). If there are no sequenced steps or derivations between the levels of grammar, then this notion cannot possibly be applied (the model is non-directional) or, alternatively, the model can be said to be all-(or non-)directional (all inter-level mapping directions are possible, so that no specific direction is imposed in the dynamic implementation of the model). In section 4.4.3, “top-down” vs. “bottom-up” Directionality was used to refer to inter-level mapping processes that begin with the conceptual intention and finish in articulation (see Levelt 1989) (from meaning into sound) vs. inter-level mapping processes that take the opposite direction (from sound into meaning). Such a notion is a metaphorical sense of Directionality related to a model’s ability to mimic the processes in which the speaker/hearer takes part when speaking/listening throughout the formalization of the way in which the various levels of a grammar interact with each other.

The notion of Directionality to be discussed in this section is related to the direction of the mapping mechanism of a grammar and the intra-level, hierarchical relations that take place within the various strata. Section 4.5.3 further compares this notion of Directionality with that supposedly involved in real-time processes (as was done above in section 4.4.3 for inter-level mapping processes). Directionality as discussed in this
section thus refers to whether the mapping mechanism of the grammar starts off with the biggest (root) unit and then goes on to smaller ones or whether it does the opposite, i.e. it processes first of all smaller units and then proceeds to increasingly bigger units. In order to make such a comparison, units must obviously be comparable, and this is where the difference between 4.4 and 4.5 resides: if different levels of representation possess different units, one cannot tell whether the mapping between units at different levels of representation are top-down or bottom-up, since it is impossible to assume e.g. that the biggest (hierarchically higher) semantic unit is smaller than the biggest syntactic one or vice versa. In other words, inter-level Directionality refers to the relative direction of mapping processes taking place between different levels of representation as a whole whereas intra-level Directionality refers to the relative direction of mapping processes taking place within one single level of representation, i.e. between units at a particular level. Such intra-level relations can be hierarchical or non-hierarchical. If intra-level relations are (considered) hierarchical, they can be either bottom-up or top-down. If a level of representation consists of hierarchically ordered, same-nature units, then mapping rules need to identify the way in which those units are related, i.e. the way in which the highest node and lower nodes are related. Directionality in this sense is top-down if the parser makes such a connection by computing the hierarchically highest node first (say, the sentence) and only then computing progressively lower branches and nodes (also called leaves). On the other hand, Directionality is bottom-up if one starts at the bottom of the parse tree with individual symbols and then connects them with rules to form bigger units. Note that the notion of parsing discussed here is not to be equated with that of interpreting a given linguistic sequence. Parsing here refers to a model’s computing or mapping mechanism, equally valid for those interfaces that map/parse production or those that map/parse interpretation. Kimball (1973: 19-20) illustrates these two parsing mechanisms:
“There are two general strategies used in parsing algorithms (cf. McKeeman et al., 1970). In the first, a tree is built for an input string by starting with the initial symbol of the grammar (that which is topmost in all trees generated by the grammar) and building a tree downwards to the terminal symbols. Such procedures are called top-down... The second type of parsing procedure involves building a tree from the bottom-up. The first action of such a parser is to assign the first m input symbols to some node, which is then placed at the top of the stack... The parse is completed when the initial symbol is the only symbol in the stack, and the input string has been completely read in”.

Note that here, as in 4.4, the difference top-down vs. bottom-up responds to a tree metaphor—a formal tree having its node on the upper-most position and its leaves being only lower. However, such relations could also be represented in other terms, say from left to right (top-down) or from right to left (bottom-up) as illustrated in (32) and (33) respectively, the former taking place forward and the latter backward (at least from a Western point of view)—or from left to right for a bottom-up approach as in (34) and from right to left for top-down approach as (35). All these relations between the root node and the leaves of a noun phrase are thus illustrated in (32)-(35) in simple phrase structure rules. While parsing rules begin with the biggest unit in (32) and (35), in (33) and (34) they begin with smaller ones. In general, a top-down parser goes from the whole expression or phrase and divides it into smaller bits until only individual items are left—thus the tree is built from the root node down into the leaves. On the contrary, bottom-up parsing builds the tree from the leaves up to the root node “starting with the leaves, using productions in reverse to identify strings of symbols that can be grouped together” (Longley & Stark 2001: 1). As mentioned above, the establishment of this kind of Directionality is of course fully dependent on whether all units involved are comparable. In (32)-(35), all units of analysis are syntactic, which means that a hierarchy (a direction) between them can be established.
4.5.2 INTRA-LEVEL DIRECTIONALITY AND THE MODELS

Intra-level Directionality in TGG, PA and FDG depends on whether certain derivation processes take place within the various levels of representation or not. If they do not, then the model has no intra-level Directionality and parsing rules are neither inherently top-down nor bottom-up. If there is derivation within the levels, then the model shows some Directionality, which can be top-down or bottom-up. Such “derivation-based generation” implies that “[s]yntactic trees are built algorithmically, either from the top down (as in pre-Minimalist theories) or from the bottom up (as in M[iminalist]P[rogram] and T[reeA]djoiningG[rammar)” (Jackendoff 2010a: 4). Accordingly, TGG predominantly shows top-down parsing rules in the formation of syntactic trees: derivations kick off on the root node (say, S) and go down to hierarchically lower units. In traditional generative approaches (Chomsky 1965, 1981), the completion of syntactic trees takes place from the higher node (the sentence, the inflection phrase, the complementizer phrase) down to lower leaves and lexical items are only inserted at the bottom of the derivation. A syntactic structure in the Minimalist Program (Chomsky 1993, 1995) is however built little by little in a bottom-up fashion: the function Merge takes two objects or lexical items that are joint/merged together and form a new phrase or set, which has the properties of the head and which is
subsequently merged with a new object. Thus the function Merge applies until the parsing of the full sentence is completed.

Contrarily to both pre-minimalist and minimalist approaches, PA shows no intra-level Directionality, since “the combinatorial character of sentences arises by “clipping together” pieces of stored structure at shared nodes. “There is no particular algorithmic order for constructing sentences: they may be built from the top down, the bottom up, or any combination . . . [Clipping] is compatible with serial, parallel, top-down, or bottom-up computation” (Jackendoff fc.: 11) -see Figure 50. Clipping is also known as unification –the identification of two nodes as being identical and unifying them such that they become one single node, bringing their respective ramifications with them and thus progressively building a tree.\(^{28}\)

Finally, FDG shows a clear intra-level hierarchy in each of its levels of representation, with all of them possessing a number of layers related to each other in a hierarchical manner. Intra-level Directionality in FDG is top-down, with parsing rules kicking off at higher layers first and lower ones only after (see e.g. Hengeveld & Mackenzie 2008: 125, 280, 311, 455 for explanations on how the IL, RL, ML and PL is built in a top-down fashion). These differences are shown in Figure 50 below.

**Figure 50. TGG, PA and FDG and intra-level Directionality**

\(^{28}\)Section 4.7.3.3 below illustrates how clipping works with an example.
This section discusses the relation between the direction inherent to natural language parsing algorithms (whether we process first small and then big units of information or vice versa) and the Directionality involved in intra-level mapping. In order to see whether the approach of a model’s intra-level parsing mechanism is coherent with that of natural language parsing algorithms, I shall first discuss the direction which natural language parsing algorithms are supposed to follow. Kimball (1973: 20) speaks of “[s]ix or seven principles of surface structure parsing”, whereby the first principle (Top-Down) is that “[p]arsing in natural language proceeds according to a top-down algorithm”, i.e. from bigger to smaller units. This algorithm could be summarily represented as in Figure 51.

**Figure 51. Postulated Directionality in natural language parsing algorithms**

The comparison between Figures 50 and 51 above is straightforward. Figures 52-54 illustrate this comparison for TGG, PA and FDG respectively. Figure 52 illustrates that Directionality in natural language parsing algorithms coincides with that in versions of Generative Grammar that are previous to the Minimalist Program (Chomsky 1957, 1965, 1981), though not in the Minimalist Program (Chomsky 1993, 1995, see also
Jackendoff 2010b). Figure 53 illustrates a different case-scenario for PA. Since nodes within one level of representation can add up either bottom-up, top-down or in a parallel fashion (Jackendoff fc.: 11), its analogy or discrepancy with natural language parsing algorithms is difficult to establish. However, “its constraints can be implemented in an order suited to particular processing tasks” (Jackendoff 2010b: 5). Finally, FDG’s intra-level organization is coherent with natural language parsing algorithms, since all four levels (IL, RL, ML and PL) are hierarchically ordered in a layered structure (Hengeveld & Mackenzie 2008: 14) that shows top-down fashion, with parsing rules operating from higher to lower leaves (see Figure 54).

**Figure 52. Directionality in natural language parsing algorithms and in intra-level mapping rules in TGG**
4.6 **DIRECTIONALITY AND DERIVATION**

That Directionality and Derivation are closely related is clear from the fact that no Derivation means no Direction. Directionality as understood in 4.3 and 4.4 refers to the
“relative” direction of derivations ("relative", because direction is never inherently bottom-up or top-down, but it is rather the source and target point(s) of the derivations that determine the direction). There appear to be four possible case-scenarios:

a) A model that does not display inter- or intra-level Derivation, thus neither inter- nor intra-level Directionality.
b) A model that displays inter-, though not intra-level Derivation, thus it displays either bottom-up or top-down inter-, though not intra-level Directionality.
c) A model that displays intra-, though not inter-level Derivation, thus it displays either bottom-up or top-down intra-, though not inter-level Directionality.
d) A model that displays both inter- and intra-level Derivation, thus also both inter and intra-level Directionality, either bottom-up or top-down.

With this classification in mind, it is to be noted that TGG, PA and FDG seem to correspond to different architectural tenets. TGG corresponds to d) a model that displays both inter and intra-level Derivation, thus also both inter and intra-level Directionality, either bottom-up (in the MP) or top-down (in pre-MP models). PA corresponds to a) a model that does not display inter- or intra-level Derivation, thus neither inter- nor intra-level Directionality. FDG seems to correspond to an architecture in between c) a model that displays intra-, though not inter-level Derivation and d) a model that displays both inter- and intra-level Derivation, thus also both inter- and intra-level Directionality. This is so for two reasons. On the one hand, intra-level Directionality is clear, since layers are organized and parsed from higher to lower nodes. On the other hand, inter-level Directionality is mainly top-down (from the communicative intention down to IL, RL, ML, PL to articulation, see Hengeveld & Mackenzie 2008: 1-3), although bottom-up inter-level feedback processes between formal units
do take place, IL and RL may be processed in tandem (see Hengeveld & Smit 2009), and once a higher level has provided enough information the parsing of lower levels may kick in - there is no need for the full parsing of higher levels to begin with the parsing of lower ones (what is known as the Depth-First principle, see Hengeveld & Mackenzie 2008: 23-25). Notably, the various levels are relatively autonomous (ibid: 4-6), a typical feature of a non-derivational (thus non-directional) model. All these reasons lead to the conclusion that FDG has a hybrid approach to Derivationality (thus to Directionality) such that it can be questioned whether it shows inter-level Directionality.

4.7 THE EXAMPLE

4.7.1 INTRODUCTION

This section analyzes the noun phrase the example in order to illustrate how the various notions of Directionality apply to TGG, PA and FDG. The example is thus analyzed in all three models and considered in relation to: a) the goal of the grammar (to analyze or generate language); b) the direction of inter-level mapping processes; c) the direction of intra-level mapping processes; d) the direction of real-time processes involved in the production and comprehension of language.

4.7.2 TGG AND THE EXAMPLE

4.7.2.1 TGG, THE GOAL OF THE GRAMMAR AND THE EXAMPLE

Generative Grammar consists of formalized rules that contain information regarding how words come together in a phrase and in which order they do so. These rules generate the sentences of a language – hence the name of the grammar (Carnie 2006: 6).
The goal of generative grammar is thus to provide the grammatical rules that are supposedly responsible for the generation of language. The role of TGG regarding the example is therefore to provide one with the rules that generate the noun phrase in a step-wise manner. TGG is thus a generator of language and, by providing the derivational history by which a sentence can be generated, it is also a language analyzer. Such phrase structure rules are given in (36) and (37) below.

(36) NP -> Det N’

(37) N’ -> (AP) N (PP)

4.7.2.2 TGG, INTER-LEVEL DIRECTIONALITY AND THE EXAMPLE

As discussed in 4.4.2, inter-level Directionality in TGG operates as illustrated in Figure 55 below. The syntactic stratum is autonomous and phonetic and semantic structures are interpreted from it via the syntax-phonology interface (PF or Phonetic Form) and the syntax-semantics interface (LF or Logical Form) respectively (in e.g. GB Chomsky 1981). Note that both LF and PF are couched in syntactic terms (Jackendoff p.c.). This is a syntactocentric model. Note that, even in MP, Move and Merge are syntactic in nature such that the syntactocentric approach is maintained (see Jackendoff 2002: 110). Accordingly, the inter-level Directionality of TGG for the example is illustrated below.

Figure 55. Inter-level Directionality in TGG and the example
4.7.2.3 TGG, INTRA-LEVEL DIRECTIONALITY AND THE EXAMPLE

As discussed in section 4.5.2, TGG adopts a top-down approach for intra-level mapping processes. This means that the root node of a phrase is parsed first and only after are smaller units parsed. The syntactic tree on the left side of Figure 56 below illustrates such a top-down approach for intra-level mapping processes in the syntactic tree for the example in pre-minimalist approaches. Note that the root node DP is parsed before hierarchically lower nodes (Det, NP, N). Lexical items are only inserted at the end of the derivation. The right-side tree illustrates the opposite case-scenario for a minimalist approach in which the parser operates in a bottom-up manner: smaller units are parsed first and then joint (merged) in order to form a bigger unit -the root node (DP).

Figure 56. Intra-level Directionality in TGG and the example

4.7.2.4 TGG, REAL-TIME PROCESSES, DIRECTIONALITY AND THE EXAMPLE

Figure 57 illustrates the inter-level Directionality of TGG (continuous, thicker arrows at the bottom) as opposed to that present in real-time processes (continuous, thinner arrows for speech production and discontinuous, thinner arrows for
comprehension). In speech production, the semantics of the example kick in first and /ˈdiɡˈzaːmpɔl/ is only pronounced after, via syntax. In speech comprehension, the opposite direction applies. The inter-level Directionality of TGG does therefore not coincide with that present in speech production or comprehension. Thus, “the syntactocentric architecture has a logical directionality: it begins with syntactic phrase construction and lexical insertion, and branches outward to phonology and semantics . . . This is quite at odds with the logical directionality of processing, where speech perception has to get from sounds to meanings . . . and speech production has to get from meanings to sounds” (Jackendoff 2002: 197).

Figure 58 below illustrates the intra-level Directionality of syntax in TGG and the postulated direction of parsing in real-time processes for the example. The direction of intra-level mapping processes in pre-MP grammars (thicker continuous, top-down arrows) is coherent with the postulated direction of natural languages (in Figure 58, discontinuous top-down arrows) from the root node down to leave nodes. The larger phrase (DP) is parsed before lower nodes are (Det, NP, N). However, in the MP (in Figure 58, thinner continuous, bottom-up arrows) lower leaves (Det, N) are parsed before the higher, root node is (DP).

Figure 57. Inter-level Directionality in TGG, real-time processes and the example
4.7.3 PA AND THE EXAMPLE

4.7.3.1 PA, THE GOAL OF THE GRAMMAR AND THE EXAMPLE

The Parallel Architecture possesses formalized rules for the production of three independent levels of syntactic, semantic, and phonological nature. Constraints are then applied to make sure that the various representations are similar enough as to correspond to the same expression. The model thus generates language (as is clear from the fact that each of the levels is conceived as an independent, generative component) and can also be used to reconstruct the production history of a given linguistic string such as the example, thus behaving as an analyzer of already-produced linguistic material.

4.7.3.2 PA, INTER-LEVEL DIRECTIONALITY AND THE EXAMPLE

As discussed in 4.4.2, inter-level Directionality in PA operates as illustrated in Figure 59 below for the example. Jackendoff thus positions PA as a non-syntactocentric model in that syntax is no longer the central component and semantics and
phonology are no longer derived from it. Note that there is no specific sequenced order for the computation of the levels of representation, and therefore no a-priori inter-level Directionality:

“The parallel constraint-based architecture is logically non-directional: one can start with any piece of structure in any component and pass along logical pathways provided by the constraints to construct a larger structure around it. For example, one can start with a piece of phonology and, via the interfaces, construct corresponding syntax and semantics; or one can start with a piece of semantics and via the interfaces construct corresponding syntax and phonology” (Jackendoff 2002: 198).

**Figure 59. Inter-level Directionality in PA and the example**

```
<table>
<thead>
<tr>
<th>Phonological structure</th>
<th>Syntactic structure</th>
<th>Semantic structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>[nou.m, [aʊ[d]n] ]</td>
<td>[aʊ [ŋ] [ɛmˈpɔɪ]]</td>
<td>[sɪŋ [ˈɛmpɔɪ]]</td>
</tr>
</tbody>
</table>
```

**Lexical structure**

"the": /ðe/ — DEF
"example": /ɪgˈzɑːmpəl/ — N — EXAMPLE

### 4.7.3.3 PA, INTRA-LEVEL DIRECTIONALITY AND THE EXAMPLE

As discussed in section 4.5, PA adopts an approach to intra-level Directionality such that “the combinatorial character of sentences arises by “clipping together” pieces of stored structure at shared nodes. There is no particular algorithmic order for constructing sentences: they may be built from the top down, the
bottom up, or any combination . . . [Clipping] is compatible with serial, parallel, top-down, or bottom-up computation” (Jackendoff fc.: 11). This means that neither the root node nor the bottom leaves are to be parsed first of all, but rather a mechanism takes place such that pieces of structure are clipped together at (all and only those) nodes that are identified as being identical.

Figure 60 below illustrates such an intra-level approach for a possible bottom-up, left-to-right syntactic tree for “the example” (see also *ibid*: 12). One can thus start computing “the”, an item listed as “Determiner” in the lexicon (a). The syntactic primitive “Determiner” is also the first node of an NP tree-structure (b), also stored in our memory. Since (a) and (b) share a “Det” node, these two can be clipped together, resulting in (c). The item “example” is stored in the lexicon as a “Noun” (d). Since “Noun” is also a node in the tree structure obtained in (c), (c) and (d) are clipped together, resulting in (e). Note that a new, bigger tree could be built for a sentence using, say, NP as a shared node (NP₁ + S [NP₁ + V + NP₂]). Shared nodes enabling clipping are underlined in Figures 60-63. If clipping is non-directional, then the procedure could take place starting with “example” as a “Noun” (a’), clipping this into the tree structure in (b’), resulting in (c’) and only then attaching “the” as “Determiner” (d’) into the tree-structure, resulting in (e’). This bottom-up, right-to-left approach is illustrated in Figure 61. If all directions are possible, I assume that Figures 62 and 63 are also possible - illustrating a top-down, left-to-right approach and a bottom-up, right-to-left approach to intra-level clipping processes, respectively.
Figure 60. Intra-level Directionality in PA and *the example* 1

(a) Det the

(b) NP

Det (AP) N (PP)

(c) NP

Det (AP) N (PP)

(d) N

example

(e) NP

Det (AP) N (PP)

the example

Figure 61. Intra-level Directionality in PA and *the example* 2

(a') N

example

(b') NP

Det (AP) N (PP)

(c') NP

Det (AP) N (PP)

(d') Det

the

(e') NP

Det (AP) N (PP)

the example
Figure 62. Intra-level Directionality in PA and the example 3

Figure 63. Intra-level Directionality in PA and the example 4
4.7.3.4 PA, REAL-TIME PROCESSES, DIRECTIONALITY AND THE EXAMPLE

Figure 64 below illustrates the inter-level Directionality of PA (thicker, continuous arrows) as opposed to the supposed direction involved in real-time processes (thinner, continuous arrows for speech production and thinner, discontinuous arrows for speech comprehension). As mentioned above, in speech production the semantics of the example kick in first and /ðaɪg'zæ:mʊpɔl/ is only pronounced after, via syntax. In speech comprehension, the opposite direction applies. The inter-level Directionality of PA for the example does not lead to any particular Directionality (based on language production or perception): “Because the grammar is logically non-directional, it is not inherently biased toward either perception or production-unlike the syntactocentric architecture, which is inherently biased against both!” (Jackendoff 2002: 198). Figure 64 below can thus be used for either production or comprehension, by simply choosing the direction relevant for a particular purpose.

Figure 64. Inter-level Directionality in PA, real-time processes and the example

Phonological structure → Syntactic structure ← Semantic structure

Lexical structure

"the": /ðaɪ/ = Det$_2$ - DEF$_2$
"example": /ɡɑːmpɔl/ = N$_1$ - EXAMPLE$_1$
Figure 65 below illustrates the intra-level (all/non-) Directionality of syntax in PA and the postulated mechanisms taking place in real-time processes’ parsing for the example from bigger to lower nodes. PA allows for a top-down as well as for a bottom-up approach (thicker, continuous, top-down and bottom-up arrows) from root (NP node) to leave nodes (Det, N) and vice versa. On the other hand, processes involved in natural language algorithm parsing take place in a top-down fashion, from root to leave nodes (discontinuous, top-down arrows).

**Figure 65. Intra-level Directionality in PA, real-time processes and the example**

![Diagram](image)

4.7.4 FDG AND THE EXAMPLE

4.7.4.1 FDG, GOAL OF THE GRAMMAR AND THE EXAMPLE

FDG generates perceivable structures from abstract representations and through abstract rules. Thus, “the role of Grammar in verbal communication can be seen as a funnel that is used to convert non-discrete communicative intentions to discrete surface structure expressions in a way that it optimally facilitates interpretability by the Addressee” (Smit 2010a: 56). From this point of view, the model can be said to actually produce language. Note that only grammatical utterances are
produced. If the model were to be turned upside-down, it would convert language into abstract units and would thus analyze, rather than produce language. If both case-scenarios are liable to implementation, the model is bi-directional in the sense introduced in (A) in section 4.2 and illustrated more extensively in 4.3. This means that FDG could either “produce” the example as well as interpret it with the static formalism being turned on its head and applied dynamically. However, in practice FDG is applied as a guide to represent in abstract terms an already-given linguistic input, i.e. the model is used to reconstruct the (derivational?) history having led to the production of such an input (at the end of the derivation, an output, an already-given surface structure). In this sense, the model is not used to generate but to analyze already-produced language.

4.7.4.2 FDG, INTER-LEVEL DIRECTIONALITY AND THE EXAMPLE

Inter-level Directionality in FDG operates in a top-down manner, from meaning to form. The semantic, morphosyntactic and phonological strata are independent (distinctive primitives and rules, see Hengeveld & Mackenzie 2008: 4-6), though “Grammar is organized in a top-down fashion in that the Interfaces generate structure based on the input they receive from higher levels” (Smit 2010: 61). Inter-level Directionality in FDG for “the example” is illustrated in Figure 66.

Figure 66. Inter-level Directionality in FDG and the example

\[
\begin{align*}
RL & \quad (\text{sing } x_i (f_i: \text{example}(f_i))(x_i))_0 \\
ML & \quad (NP_i: [[(GW_i: \text{the}(GW_i))(NW_i: \text{example}(NW_i)))](NP_i)) \\
PL & \quad (PP_i: [[(PW_i: \text{aig'zom.m;pai/}(PW_i))](PP_i))
\end{align*}
\]
4.7.4.3 FDG, INTRA-LEVEL DIRECTIONALITY AND THE EXAMPLE

As discussed in section 4.5.2, FDG adopts a top-down approach as far as intra-level relations are concerned, since “more global aspects of the Speaker’s communicative intention are handled prior to lower-level ones” (Smit 2010: 57). Thus, hierarchically higher units (bigger units) are parsed before hierarchically lower leaves (smaller leaves). Figure 67 below illustrates the static morpho-syntactic representation for the example. Figure 68 translates this into a dynamic tree graphic. Note that the tree structure avoids the need to use co-indexation, since there is no need for closing variables.

Figure 67. Intra-level Directionality in FDG and the [static] example

\[ ML (\text{Np}_1; ([\text{Gw}_i; \text{the}(\text{Gw}_i)]; \text{Nw}_i; \text{example}(\text{Nw}_i)));(\text{Np}_j)) \]

Figure 68. Intra-level Directionality in FDG and the [dynamic] example

4.7.4.4 FDG, REAL-TIME PROCESSES, DIRECTIONALITY AND THE EXAMPLE

Figure 69 below illustrates the inter-level Directionality involved in the dynamic construction of an underlying representation for the example. Top-down, thicker, continuous arrows correspond to the processes involved in FDG while thinner arrows correspond to those involved in language
production (top-down, continuous) and in language comprehension (bottom-up, discontinuous). The parallelism with speech production is clear, since interfaces in the representation of the example go from meaning (RL) via syntax (ML) down to sound (PL). Note that the model is incremental, which means that e.g. the phonology of the could kick in as soon as its morphosyntactic counterpart is filled in, not having to wait for the whole previous level to be saturated (see the “Depth-First Principle” in Hengeveld & Mackenzie 2008: 23-25).

Figure 70 below illustrates the intra-level Directionality of morpho-syntax in FDG and the postulated mechanisms taking place in the mapping involved in real-time processes for the example. Discontinuous arrows illustrate the processes that take place in natural language mapping algorithms while continuous lines illustrate processes in FDG. The mapping mechanism of the model is thus coherent with the direction of natural language mapping, since it goes from root to leave nodes: hierarchically higher nodes (bigger units) are parsed before lower nodes are (smaller units).

Figure 69. Inter-level Directionality in FDG, real-time processes and the example

$$\text{RL} \quad \text{sing} \chi_1;\text{f;example}(f_1)(\chi_1)\downarrow$$

$$\text{ML} \quad \text{Np;}[\text{GW;}\text{the(GW)}](\text{NW;}\text{example(NW)})](\text{NP})$$

$$\text{PL} \quad \text{PP;}[\text{PW;}\text{hæm, pæl}/(\text{PW})](\text{PP})$$
4.8 CONCLUSIONS: FOUND IN ALL DIRECTIONS

Sections 4.2-4.5 have illustrated the various, distinctive notions of Directionality. These, however, have proved to be interrelated. On the one hand, inter-level and intra-level Directionality have appeared to be closely related. If a model of language shows hierarchical intra-level Directionality – i.e. if it is not totally bi-directional-, then it is only logical to assume that it will also show some kind of intra-level hierarchy and Directionality. Such is the case of TGG, which shows inter-level and intra-level Directionality, and of PA, which shows none (all inter-level directions being allowed, and intra-level mappings being also free as to order of sequence and direction). Regarding FDG, it is also the case that inter-level and intra-level Directionality co-exist with the exception of the “Depth-First Principle”, by which lower units may be processed before a whole bigger, higher unit is processed in the presence of enough information at higher levels to begin the process at lower levels – also applicable for PA. As to a model’s mirroring the Directionality involved in natural language processes, it is also normally the case that either production and/or comprehension are mimicked, and that the parsing within one level proceeds from bigger to smaller units as it supposedly does in the parsing of natural languages. In the case of TGG, however, neither speech comprehension nor speech production is mirrored in
inter-level Directionality. Regarding intra-level Directionality, however, pre-minimalist versions do propose mapping mechanisms that go from root to leaves and thus mirror the Directionality involved in natural language parsing algorithms. As for PA, both speech comprehension and production can be accounted for in inter-level Directionality, though none of them are explicitly chosen – all interfaces are allowed for. Intra-level Directionality from bigger to smaller units as it supposedly applies to natural language parsing algorithms is however not accounted for in “clipping”, since unification can be done both top-down and bottom-up – clipping is however consistent with the incrementality of natural language parsing algorithms as discussed in Ferreira (1996), Ferreira & Swets (2002) and Wheeldon & Lahiri (1997). As to FDG, inter-level Directionality also reflects – whether purposefully or not – speech production and, should it be turned on its head, speech comprehension. Its hierarchical intra-level organization also reflects the top-down, from-root-to-leaves parsing mechanism possibly involved in natural language parsing.

4.9 SUMMARY

In this chapter, I have discussed the third architectural dimension of this study, Directionality which, together with Distribution and Derivation, constitutes one of the main architectural tenets of a grammatical theory. Directionality can be interpreted in many different ways. I have introduced some notions of the term in section 4.2. In the subsequent sections, I have attempted to further explain each of the notions of Directionality. Accordingly, section 4.3 deals with Directionality as a model’s attempt to analyze and/or produce language. Section 4.4 illustrates Directionality as the inter-level direction of mapping mechanisms. Section 4.5 approaches Directionality as the intra-level, hierarchical relation between units within a single level of representation. Both sections 4.4
and 4.5 contain a subsection on the relation between the notion of Directionality at hand (either of inter-level or of intra-level mapping processes) and that involved in real-time language processes. Section 4.6 has examined the close relation between Directionality and Derivationality. Section 4.7 has illustrated the way in which TGG, PA and FDG approach each of the notions of Directionality. Finally, section 4.8 has examined the relation between the different notions of Directionality.