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RESEARCH ARTICLE

Scientific modelling in generative grammar and the dynamic turn in syntax

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Abstract In this paper, I address the issue of scientific modelling in contemporary linguistics, focusing on the generative tradition. In so doing, I identify two common varieties of linguistic idealisation, which I call determination and isolation respectively. I argue that these distinct types of idealisation can both be described within the remit of Weisberg's (J Philos 104(12):639–659, 2007) minimalist idealisation strategy in the sciences. Following a line set by Blutner (Theor Linguist, 37(1–2):27–35, 2011) (albeit for different purposes), I propose this minimalist idealisation analysis for a broad construal of the generative linguistic programme and thus cite examples from a wide range of linguistic frameworks including early generative syntax (i.e. Standard Theory, Government and Binding and Principles and Parameters), Minimalism (Chomsky in The minimalist program, MIT Press, Cambridge, 1995), the parallel architecture (Jackendoff in Foundations of language: brain, meaning, grammar, evolution, Oxford University Press, Oxford, 2002) and optimality theory (Prince and Smolensky in Optimality theory: constraint interaction in generative grammar, 1993/2004). Lastly, I claim that from a modelling perspective, the dynamic turn in syntax (Kempson et al. in Dynamic syntax—the flow of language understanding, Blackwell Publishers, Oxford, 2001; Cann et al. in The dynamics of language: an introduction, Elsevier, Oxford, 2005) can be explained as a continuation, as opposed to a marked shift (or revolution), of the generative modelling paradigm (despite radical theory change). Seen in this light, my proposal is an even broader construal of the gen-

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erative tradition, along scientific modelling lines. Thus, I offer a lens through which to appreciate the scientific contribution of generative grammar, amid an increased resistance to some of its core theoretical posits, in terms of a brand of structural realism in the philosophy of science and specifically scientific modelling.

Keywords Models · Generative grammar · Dynamic syntax · Idealisation · Philosophy of science

1 Introduction

The generative tradition in linguistics took the form of a scientific revolution in the middle of the twentieth century. The techniques and methodology which came along with the movement claimed to place the study of language at the level of an empirical, naturalistic science which would eventually be subsumed by biology or neurophysiology. Since this time, arguments have been proffered which challenged this claim on ontological grounds (Katz 1981; Carr 1990; Katz and Postal 1991), methodological grounds (Soames 1984; Hintikka 1999; Devitt 2006) and linguistic grounds from the various competing frameworks, some of which were spawned from the initial generative approach (Pustejovsky 1995; Prince and Smolensky 1993/2004; Kempson et al. 2001; Jackendoff 2002).

In this paper, I take no position on the scientific status of linguistics or its ontological underpinnings. I do, however, offer a lens through which to appreciate the scientific contribution of the generative tradition in linguistics (whether or not it is deemed to be a "science" at the end of the day). This account is in terms of the specific type of modelling practice that this framework brought to the study of natural language(s), namely minimalist models idealisation (Weisberg 2007). This is a type of modelling that is ubiquitous in the hard sciences such as physics and chemistry. I use the above claim to provide an explanation of how the diverse and competing approaches to linguistics, specifically of the dynamic variety (Kempson et al. 2001), are related to the generative one and a continuation (as opposed to a revolution) of the modelling strategies of the initial scientific revolution in linguistics. I argue that the generative tradition can thus be appreciated for ushering this type of modelling practice into the study of language and more broadly construed in terms of it.

This analysis does not presuppose any evaluative benefits or disadvantages of specific modelling trends, nor does it offer comments to that effect. In addition, it does not aim to exhaustively capture all the modelling strategies employed by linguists, only some of the salient ones.

In the first section, I discuss modelling in the sciences with a focus on the notion of minimalist idealisation in model-building. This is by no means an attempt at a comprehensive account of the vast and diverse philosophical terrain of scientific modelling, of which I have no intention (or need) to charter at this time. In the next section, I attempt to provide an analysis of linguistic modelling in terms of minimalist idealisation, drawing from the core tenets of the generative programme from the initial

Standard Theory (1965) to Minimalism (1995).[1] I identify two types of idealisation, namely determination and isolation, both of which I argue are species of minimalist idealisation (Weisberg 2007, not to be confused with Minimalism in Generative Grammar). In Sect. 4, I attempt to extend this analysis to the dynamic turn in syntax and other related frameworks such as Optimality Theory and the Parallel Architecture. In the penultimate section, I discuss frameworks and types of frameworks which do not build their linguistic models by means of minimalist idealisation. Lastly, I revisit the issue of why the modelling perspective is particularly illuminating in the case of contemporary linguistics.

2 Modelling and idealisation

The first question to ask is 'why modelling'? There are various methods involved in scientific theorising and modelling is just one particular subset of these methods. A beginning of an answer can be provided by appreciating how modelling differs from other types of theorising. As the term suggests, the theorist starts with a model or an indirect representation of the target system. In this case natural language. She then describes the model assuming that given its resemblance to the target system, the descriptions will be true of (or useful to understanding) the target system itself. Therefore, in what follows, I will be assuming that a grammar is a model of natural language or select portions of it (I will readdress this issue in Sects. 3 and 8).

Scientific modelling is a burgeoning field within the philosophy of science. The idealisations and abstractions involved in modelling have been argued to be pervasive in the sciences and seem to inform and shape much theorising in fields from physics to biology (see Van Fraasen 1980; Cartwright 1983; Suppe 1989). In this section, I will focus on idealisation as it plays a central role within the modern linguistic approach to natural language.

The terms 'idealisation' and 'abstraction' are sometimes used interchangeably in the literature. I will follow Thomson-Jones (2005) in distinguishing between these concepts. Thus, idealisations involve misrepresentation of the target system or specific aspects of it, while abstractions merely omit certain factors. "[W]e should take idealization to require the assertion of a falsehood, and take abstraction to involve the omission of a truth" (Thomson-Jones 2005, p. 175). Thomson-Jones cites Chomsky's invocation of an ideal speaker-listener in the study of linguistic competence as

[1] In terms of terminology, I will follow the framework outlined by Kuipers (2007) for the sciences generally and used by Tomalin (2010) for the development of generative linguistics. In this framework, there is a hierarchy of scientific categories roughly as follows. At the top are (1) research traditions, e.g. Generative Linguistics itself (including phonology, syntax etc.), which are instantiated by (2) research programmes such as generative grammar (further subdivided into Standard and Extended Standard Theory, Minimalism etc.) or the parallel architecture, optimality theory which in turn have (3) core theories (such as syntactocentricism or recursion) and finally (4) specific theories of particular phenomena which share core theoretical tenets. "This seems reasonable since the phrase 'generative grammar' is standardly used to refer to different theories of generative syntax that have been proposed during the period 1950s-present, and, given this, it would be misleading to classify GG as being simply a 'theory' (Tomalin 2010, p. 317)".

a canonical case of idealisation.[2] Another case of idealisation is Fisher's Principle in evolutionary biology that states that the sex ratio of most animal species is 1:1 based on a hypothetical model which postulates a fictitious three-sex organism.

At first glance, this definition of idealisation might seem at odds with standard semantic accounts of modelling, such as Giere (1988), which assume resemblance relations (often in the form of morphisms) between the model and the target system. However, the idea of resemblance relations still holds even in an extreme case such as the Fisher model, in the form of a hidden *ceteris paribus* clause. We assume that all other factors of the biological world are held constant for the distortion or idealisation to explain the evolutionary stability (or evolutionary stable strategy, ESS) of the 1:1 sex ratio. In this way it resembles a *reductio* or constructive proof in logic and mathematics, in which the laws of logic (such as noncontradiction) are held constant while an absurd hypothesis is entertained (and eventually rejected). We will return to the issue of explanation and *ceteris paribus* hedges briefly in the next section.

As previously mentioned, for Godfrey-Smith, "the modeler's strategy is to gain understanding of a complex real-world system *via* an understanding of simpler, hypothetical system that resembles it in relevant respects" (2006, p. 726). The important phrase here is "in relevant respects". The relevant features of the real world which the model resembles might not be the properties which we are aiming to explain directly, these could be distorted if the model resembles the target system in other respects. In fact, it is unclear how idealisation would operate if there were no resemblances at all between the models and reality. Imagine a distortion or idealisation inserted into a system which in no way resembles the real world or the laws of nature. Not only would it be extremely difficult to predict the effect of such a distortion but it would be unclear as to the role of its introduction in an otherwise distorted world.

Of course, idealisations may be introduced for a variety of reasons. Weisberg (2007, p. 641) identifies a common type of idealisation in the hard sciences called "Galilean idealisation" which introduces distortions for the sake of computational tractability. A frictionless plane in physics is often referenced as a case of such an idealisation. No such thing exists in the real world and yet the idealisation is extremely useful in theoretical and applied mechanics. Formal language theory in linguistics possesses similar idealisations. In this field, natural languages are taken to be sets of uninterpreted strings organised according to their complexity. Of course, no natural language is wholly uninterpreted, but this idealisation is essential for much of the work done in computational linguistics and the construction of various grammar formalisms. Before moving on to the nature of linguistic idealisations such as these, let us consider what role they might play in the explanation of linguistic phenomena.

[2] "Linguistic theory is concerned primarily with an ideal speaker-listener, in a completely homogeneous speech-community, who knows its (the speech community's) language perfectly and is unaffected by such grammatically irrelevant conditions as memory limitations, distractions, shifts of attention and interest, and errors (random or characteristic) in applying his knowledge of this language in actual performance." (Chomsky 1965, p. 4).

3 How the laws of linguistics might lie

In the philosophy of physics, Cartwright (1983) famously argued that the explanatory power of the fundamental laws of physics lies precisely in their falsehood. Her *simulacrum* account of explanation relies on the idea that the fundamental laws are not strictly true of observable reality but only true of highly idealised objects of scientific models. Reference to these latter objects are usually prefaced with *ceteris paribus* clauses which impose conditions never actually fulfilled in the phenomenal world (or the world of appearances, surface form in linguistics). On this view, models occupy a central explanatory role, i.e. "to explain a phenomenon is to construct a model that fits the phenomenon into a theory" (Cartwright 1983, p. 17). Intriguing though this idea might be, it is generally considered to be quite a contentious matter in the philosophy of science and physics [see Elgin and Sober (2002) for a reversal of Cartwright's conclusions].

Nevertheless, in the case of linguistics this account seems somewhat more applicable. The Conceptualism (or Mentalism) upon which the generative programme is based seeks ultimately to explain linguistic laws (or rules of the grammars) in terms of biological or neurobiological reality. Thus, linguistic models, which are constituted by abstract grammar rules, are not true of real world languages (which rarely met the requirements of such rules inviolably) and it is not even clear how they could be true of actual neurobiological states (which involve neural processes and synaptic connections etc.). The explanatory power of linguistic theories lies in the rules of the grammars of idealised languages, or I-languages (thus, adding an 'I' to the usual definition).

In this way, the rules of generative grammars can be characterised as one of Stainton's (2014) options for an explanation of the field in stating that "the practice is sloppy, loose talk—which is strictly speaking false, and will eventually have to be reconstructed as corresponding truths about mental states and processes" (8).[3] Ignoring the pejorative connotations of the previous statement, the competence-performance distinction which rests on the idealisation of a perfect linguistic community, incapable of error, further suggests that this picture might not be inappropriate for the rules of generative grammar. Whether or not we adopt an additional idealisation of core grammar to which the rules apply[4] or the faculty of language narrowly construed (á la Chomsky et al. 2002), the rules or laws of linguistics are not strictly true of surface expressions but rather of highly idealised and internalised linguistic structures of the grammars. In addition, generativists are insistent that grammar rules do not pertain to expressions of public languages or E-languages but rather to the I-languages which in turn stand proxy for mental states and eventually brain-states to be explained by neuroscience. They are similarly insistent that the requisite cognitive and neurological structural realisations are forthcoming. Thus, the laws of linguistics might be be doubly mendacious (again not in a pejorative sense), in firstly being directed at explaining idealised structures of idealised communities of cognisers and secondly in suggesting as candidate targets of the models mere place-holders for later biological

[3] He eventually goes on to reject this interpretation of generative linguistics.

[4] See Pullum (1983) for problems with the core grammar postulate.

instantiation. This is different from the usual taxonomy assumed in the sciences since chemical or biological generalisations are not usually assumed to be reducible to the generalisations of physics but rather produce their own genuine level of explanation. In the following section, I will delve deeper into the nature of linguistic idealisation and show that it is a variant of modelling strategies used in the other sciences and thus the goal of eventual biological incorporation might not be unrealistic. In this way, the explanations involved in the models of linguistics can be shown to be related to those of the other sciences while retaining some aspects of the idea that linguistics is distinctive in its scientific status.

4 Minimalist idealisation from ST to minimalism

In this section, I investigate two kinds of idealisation both aimed at discovering the minimal causal basis responsible for a particular property or phenomenon of the target system. It is an idealisation in the sense I have been using, in that the models make no attempt to represent the target phenomenon in its complete state or "de-idealise" to include extracted phenomena. In other words, we misrepresent the target system as involving only the core causal factors we deem necessary for the explanation or generation of a given phenomenon or property. Weisberg (2007) describes minimalist idealisation as "the practice of constructing and studying theoretical models that include only the core causal factors which give rise to a phenomenon" or "put more explicitly, a minimalist model contains only those factors that *make a difference* to the occurrence and essential character of the phenomenon in question" (Weisberg 2007, p. 642). If this were mere omission, then we would be able to reintroduce the abstracted phenomenon into the model.

Consider the frictionless plane example again in mechanics. If we include friction (or fluid/air resistance) into the model, the predictions will fail, since these forces result in a loss of energy and thus a loss in speed and acceleration among other things. Admittedly, these elements are reintroducable into the system (and perhaps indicative of Galilean idealisation). A better example of minimalist idealisation is presented in Weisberg (2013, p. 100).

> A classic example of a minimalist model in the physical sciences is the one-dimensional Ising model. This simple model represents atoms, molecules, or other particles as points along a line and allows these points to be in one of two states. Originally, Ernst Ising developed this model to investigate the ferromagnetic properties of metals. It was further developed and extended to study many other phenomena of interest involving phase changes and critical phenomena.

The generative tradition was largely motivated by such modelling practices, specifically through two versions of minimalist modelling, which I call *minimal determination* and *isolation* respectively. A similar genesis is attributed to generative grammar by Tomalin (2006) who provides strong evidence that, following Goodman (and Quine), Chomsky took principles of economy and simplicity to be constitutive of the process of grammar construction.

> From the very beginning, then, Chomsky seems to have been persuaded that considerations of simplicity were intimately involved in the processes of grammar construction […] With particular reference to syntactic theory, one of the implications of Goodman's views concerning the critical importance of simplicity criteria in constructional systems is that the reasons for wanting a grammar to be as simple as possible are the same as for wanting a grammar at all (113).

The strategy is the same as that described by Weisberg concerning minimalist idealisation or in which "[t]heorists often begin a project by trying to determine what kind of minimal structures could generate a property of interest" (2007, p. 650). In addition, Chomsky himself acknowledged the role of modelling and idealisation (as I have defined it) in the linguistic process as integral as early as *Syntactic Structures*.

> Precisely constructed models for linguistic structure can play an important role, both negative and positive, in the process of discovery itself. By pushing a precise but inadequate formulation to unacceptable conclusion, we can often expose the exact source of this inadequacy and, consequently, gain a deeper understanding of the linguistic data (1957, p. 5).

Before moving on to a more thorough discussion of minimalist idealisation practices, I shall state (following Blutner 2011) five core characteristics of the generative programme in linguistics.[5] It should be noted that these characteristics do not form a necessary and sufficient set or definition at the level of research tradition but rather a guide to the theoretical underpinnings of subsequent research programmes and how different specific theories developed from core theories or propositions in the sense of Kuipers (2007) (see footnote 1). The consequence of a complete characterisation (in term of (1)–(5) below) at the research tradition level would be tantamount to the exclusion of *Syntactic Structures* from the generative tradition. Needless to say, any characterisation of generative research tradition which banishes this founding text would be impoverished at best.[6]

1. Autonomy of Syntax: The methodological posit that the core "generative" component in natural language production is the computational system which produces the set of grammatical expressions. This system operates independently of the semantic, pragmatic and phonological components of the grammar (or in Blutner's words "there exists an encapsulated system of purely formal generalizations orthogonal to generalizations governing meaning or discourse" (2011, p. 27).
2. Universal Grammar: The claim that despite surface differences between the world's languages, there is a set of genetically endowed linguistic universals common to all possible human languages (developments such as the Principles and Parameters framework allow for external linguistic input to shape the initial settings of the grammar).[7]

[5] Although I have substituted his third tenet for the Universal Grammar postulate and my description of the rule-based view is somewhat different to his description of it.

[6] I thank an anonymous referee for cautioning me on this point.

[7] There is a distinction between the idea that there are universal typological properties which are common to all natural languages (in surface syntax, morphology etc.) [for instance, the wealth of research which flowed from Greenberg (1963)], and the claim that there are underlying universal principles of human

3. Innateness Hypothesis: A rationalistic approach to natural language acquisition in which human infants are endowed with a linguistic system prior to encountering any input. Often motivated by the "poverty of stimulus" argument [for some interesting empirical support for innate linguistic biases in child language acquisition, see Culbertson and Adger (2014) and Culbertson and Newport (2015)].
4. Competence-performance distinction: Linguistic theory is concerned with an ideal linguistic competence and not necessarily with the various aspects of performance or actual parsing and processing in real-time.
5. Rule-based Representationalism: This is the view that the posits of the grammatical theory or rules of the grammar are actual features of the human agent or 'cognizer' (actual goings-on in her mind/brain) at some level of deep neurophysiological embedding. To 'know' or have a language on this view is to have subconscious (tacit or implicit) access to these rules.

Blutner goes on to argue that a broad construal of the generative programme in terms of these aspects (or similar ones) should encompass frameworks such as Jackendoff's architecture of the language faculty, Pustejovsky's generative lexicon and the optimality theory of Prince and Smolensky. Importantly for my purpose, the dynamic syntax framework rejects many (if not, all) of these tenets outright and therefore I believe that the extension of this approach under the auspices of the generative tradition itself cannot follow the same lines as Blutner proposes for the other frameworks. In other words, the dynamic programme constitutes a genuine core theory change. I do not intend to dispute this point or argue that dynamic syntax is generative syntax in disguise. Rather, I propose an even broader construal of the generative tradition, along scientific modelling lines. This analysis maintains the broad construal of Blutner's proposal but extends it in terms of modelling strategies as opposed to theoretical posits, i.e. generative linguists and dynamic linguists (and linguists of the other generative persuasions) build their models in similar ways, using similar strategies. It is on to these strategies that the next section moves, while in Sect. 7, I also mention contemporary frameworks which do not follow these practices.

4.1 Minimal determination

Minimal determination is perhaps the most explicit version of minimalist modelling in linguistics. One criticism of the pre-Chomskyan linguistic paradigm (the Structuralism of Bloomfield, Hockett and others) was its alleged inability to explain linguistic creativity (see Searle 1974). By focusing on statistical or classificatory aspects of specific corpora (of actual speech), this approach limited itself to dealing with finite tokens of natural language and thus could not account for the linguistic creativity or the idea that we possess a capacity for indefinite linguistic novelty in both production and comprehension.

Footnote 7 continued
language which are relevant to explaining phenomena such as language acquisition. GG is only committed to the latter. I thank an anonymous reviewer for stressing the need for clarification here.

It was in drawing inspiration from computability theory that the early generative tradition placed the notion of a generative grammar (subclass of a Post-canonical system or Turing machine) at the forefront of the discipline. The idea was to capture the discretely infinite set of expressions of natural language *via* finite means. In the Standard Theory (1957–1965) or ST, phrase-structure rules performed this task. Certain rules allow for recursive structures in terms of embedding or self-reference, such as simple rules for coordination '$NP \rightarrow NP$ and NP' or more complex rules such as '$S \rightarrow NP\ VP$' and '$VP \rightarrow V\ S$' for embedded sentences. Think of this as a loop in a push-down automaton [the class of automata associated with context-free (CFG) or phrase structure grammars (PSG)] which allows for unbounded iteration and thus a discretely infinite set of new expressions, e.g. Thabo is intelligent; [Thabo is intelligent] and [Thabo is brave]; [Thabo is intelligent] and [[Thabo is brave] and [Thabo is short]] etc. or 'Sipho said that [Lungi mentioned that [Thato believed that p]].[8] The product of the phrase structure rules (or rewrite operations) contributes to the DEEP STRUCTURE or underlying syntactic form. This structure feeds into the TRANSFORMATIONAL component of the grammar which is responsible for surface forms of expressions (through movement and deletion). ST was a progression on the purely classificatory notion of transformational grammar of Harris (1951) and Chomsky's own more derivational view in *Syntactic Structures* (1957) with the addition of a lexical component or lexicon which received input from the phrase structure and inserted lexical items into the deep structure. Kernel sentences, simple declaratives devoid of any modification which can be combined to form complex sentences, were also eschewed in favour of deep structure which could represent surface forms more minimally. This framework affirms the fourth tenet of the generative programme, namely the competence-performance distinction. "ST does not attempt to answer the questions of language perception and production […] rather than directly relating meaning and expression, it relates them indirectly, through deep structure." (Langendoen 1998, p. 242). A direct relation (or determining relation) of meaning to expression is a matter of a performance grammar on this view and thus outside of the scope of linguistic theory.

ST, I claim, involves an example of *minimal determination* in the rewrite rules of the phrase-structure. In order to explain the creative aspect of natural language (or the specific examples of iterative structures such as conjunction and adjectival

[8] Recursion is a tendentious topic in theoretical linguistics. It is not my intention to be embroiled in that controversy here, although I will offer some comment on the topic in Sect. 8. The core idea is that recursive functions introduce a property of self-reference. This usually involves two steps. One which specifies the condition of termination of the recursion or the base case and the recursive step which reduces all other cases to the base. The Fibonacci sequence and factorial functions are examples of this procedure, so too is Bar-Hillel's (1953) definition of a grammatical French sentence [see Tomalin (2006) for further discussion]. In fact, the examples cited above are not 'perfect' cases of recursion as the subordinate clauses are not technically "contained" in the larger structure. Centre-embeddings might be more illustrative in this case. For the controversy surrounding the history of this specific construction see Sampson (2001). The general class under which centre-embedding is subsumed is so-called 'nested recursion' as in [The man [the boy [the girl kissed] hit] filed a complaint] (van Hulst 2010, p. xxiv). Again, it is questionable whether or not such constructions naturally occur in language (see Karlsson 2010). However, the term 'recursion' has been used in a variety of ways in linguistics [see Tomalin (2007) and Lobina (2010) for an extension of these uses] so much so that iterative constructions and embeddings are not clearly distinguishable purely on the grounds of recursive characterisation.

modification), i.e. the property of interest, we postulate a finite set of rules which allow for recursive structure and thus for infinite expression. The rule formulation is not descriptive but rather generative in the sense that it is supposed to represent multiple structures and with recursive elements potentially infinite structures. There are other ways to account for creativity. For instance, we could argue that we have a very large set of stored linguistic expressions (wholesale, not piecemeal) and we instantiate these expressions when prompted by experience [see Evans (1981) for a comparison between the two methods]. However, this explanation would not be a case of minimalist idealisation in the same way that assuming we possess a finite rule system capable of infinite output is. The definition I propose can be stated in this way:[9]

Minimal determination: The explanation of a complex linguistic phenomenon or property is provided by a model which includes only the interaction of the smallest possible units underlying the phenomenon/property.

The above suggests an explanatory dimension to the modelling of a given phenomenon *via* the least possible units. In fact, the syntacto-centrism itself (tenet 1) of the generative programme can be understood in terms of minimal determination. Syntax is claimed there to be the single "generative engine" of the language faculty as opposed to multiple such mechanisms. The idea is that we understand 'determination' in linguistics to be a means of providing explanations to causal questions. For example, if we want to explain why language users are prone to judging certain kinds of sentences (displaying certain kinds of syntactic structure) as felicitous or not (grammatical), then we do so by stipulating the least amount of rules (of only a particular kind) which generate that type of sentence to model this behaviour. Thus, the rules of the grammar/model facilitate knowledge of the real world system through idealised models. The actual output of linguistic competence need not be infinite in reality. This is similar to when physicists explain the superconducting properties of certain metals *via* the Bardeen–Cooper–Schrieffer model which involves phase transitions and a thermodynamic limit, i.e. the non-veridical postulation of infinite particles. Infinity is assumed in the model to make certain predictions and characterisations simpler. This latter model may be an obvious candidate for idealisation but even less abstact examples can suffice to show that "the endeavor is *explanation*; the feature of idealization […] is the deliberate falsification of the causal workings of the system whose behavior is to be explained" (Strevens 2007, p. 1). Strevens describes how Boyle's Law is usually accompanied by a "causally distorting explanation" which involves ignoring the long range attractive forces between molecules and the collisions they exhibit *inter alia*. Similar idealisation is involved in explaining linguistic phenomena on this account. For instance, garden path phenomena (as in the example below) are notoriously difficult to parse by real speakers, yet they do correspond to syntactic rules, as in the famous case below.

[9] Of course, in many frameworks such as the Parallel Architecture and Dynamic Syntax, sets of stored expressions are included in the grammar in terms of idioms, quotations, songs etc. There is nothing incompatible with stored expressions and compositional grammar rules in principle.

1. The horse raced past the barn fell.

The rules of the grammar do not strictly correspond to speaker judgements in these cases but rather, following Cartwright, they correspond to the idealised structure that is the speaker's I-language or state of the language faculty. They are true of a model. Thus, the model/grammar is not a direct representation of the target system, since speakers tend not to be able to parse these sentences effectively or immediately despite their grammaticality.

The Extended Standard Theory or EST of the 70's (Chomsky 1973; Jackendoff 1977), introduced further minimalist idealisations into the generative approach. On this account, the phrase-structure rules are simplified even further to account for a broader range of linguistic universals (or phrasal categories) through the binary branching of the X-bar theory. In contrast to the many phrase structure rules of transformational grammar and ST, we now have only three types of rules which generate all the requisite structures. The three rules are (1) a specifier, (2) an adjunct and (3) a complement rule, represented respectively below (where X' is a head-variable and XP, YP, ZP, WP are arbitrary phrasal categories determined by that head).

1. Specifier rule: $XP \rightarrow (YP)X'$ or $XP \rightarrow X'(YP)$
2. Adjunct rule: $X' \rightarrow X'(ZP)$ or $X' \rightarrow (ZP)X'$
3. Complement rule: $X' \rightarrow X(WP)$ or $X' \rightarrow (WP)X$

In contrast to the redundancy of phrase-structure rules, X-bar theory vastly overgenerates the grammatical or well-formed linguistic structures and needs to be reined in by various other devices (such as theta-grids etc.). But the move is minimalist nonetheless. "As first suggested by Chomsky (1970) […] we might be able to eliminate the redundancy and increase our explanatory power by generalizing the phrase-structure rules" (Poole 2002, p. 47). It is also an idealisation in the sense discussed above. Once again, the model of grammar homes in on the minimal causal basis necessary for grammatical representation. In addition, we move closer to an account which respects the innate structure of the language faculty, the third core characteristic of the generative approach (mentioned in Sect. 4). In *Aspects of the theory of Syntax* (1965), Chomsky differentiates between three nested kinds of adequacy conditions for a theory of grammar, each more inclusive than the last. The three related linguistic desiderata are (1) observable linguistic performance, (2) native speaker judgements and (3) language acquisition. The first is the class of *observationally adequate grammars* which are those grammars which only account for corpora or observed utterances of speech. Naturally, these do not give us much traction on (2) and (3). Chomsky then suggests a class of *descriptively adequate grammars* (DAGs) which aim to capture the psychological facts of native speaker intuitions, thereby addressing (1) and (2). However, these latter grammars are inadequate on count (3) and thus require us to ascend to the level of *explanatorily adequate grammars*. By minimising the set of rules which learners have to acquire, we approach the explanatory adequacy necessary for a story about language acquisition.

> [L]inguistics was supposed to be embeddable into cognitive science more broadly. But if this is the case then there is a concern about the unchecked proliferation of rules-such rule systems might be descriptively adequate, but they

> would fail to account for how we acquire a language-specific grammar (Ludlow 2011, p. 15).

The X-bar innovation also pulled in the direction of universality as the new grammar rules or schemata could represent a greater number of tree (or hierarchical) structures and thus capture more of the constituents of a greater number of world languages, again with minimal resources. As *per* the definition of minimalist idealisation, we are only interested in the core causal factors involved in grammatical production, i.e. the models of ST and EST only contain these factors. In the opposite direction, Newmeyer (2002) describes the generative semantics project as attempting to model too much and his words are particularly illuminating within the scope of the current section.

> The dynamic that led generative semantics to abandon explanation flowed irrevocably from its practice of regarding any speaker judgement and any fact about morpheme distribution as a *de facto* matter for grammatical analysis […] Attributing the same theoretical weight to each and every fact about language had disastrous consequences (121).

Another way of putting this is that the models were moving from minimalist idealisations to more comprehensive representations of the target systems (often including pragmatic phenomena such as implicature). In the next section, I describe another variety of minimalist idealisation modelling, one which, I think, is crucially involved in both the Government and Binding (1981) and Minimalist (1995) approaches.

4.2 Isolation

Natural language, and the linguistics which attempts to study it, is a diverse object of inquiry. Any theory which aims at a comprehensive account of its nature has to acknowledge the diverse factors involved in its explanation. When discussing syntax, semantic considerations invariably enter into certain descriptions (often captured by selectional restrictions on lexical items), when doing semantics, phonological aspects can be relevant (e.g. prosody) or pragmatic features (implicature, context shifting, metaphor, sarcasm etc.). Standard generative grammar places syntax at the centre of the language faculty and banishes these other aspects to various post-computational spell-outs or logical form. However, some proponents, such as Jackendoff in his Parallel Architecture (2002), jettison the syntacto-centric account and describe the language faculty as involving multiple generative mechanisms and interface principles between them. Dynamic syntax too rejects the centrality of syntax but goes one step further than Jackendoff in rejecting its autonomy likewise. The models of the generative tradition aim not only to identify the minimal properties which "determine" (in the causal sense of produce) the intended aspect of the target system but also the relevant causes involved in this determination. This is where isolation comes in. Isolation is the modelling strategy which involves isolating or separating out the specific types of causal explanations deemed relevant to the phenomenon we are interested in producing.

The scientific modelling involved in generative linguistics often includes a property known as "modularity". Modularity is the property of a system which involves separating it into discrete, individual subsystems which contribute to the system's overall

organisation and operation. *Isolation* is similarly the technique of building models of these separate subsystems independently of one another (or as much as possible). One can think of it as the modelling technique which corresponds to the property of modularity.[10] So the definition, I offer, is as follows:

> Isolation: The separation of a system into distinct minimal causal models for the *determination* of separate (but potentially related) properties or families of properties.[11]

This type of idealisation not only involves compartmentalising causal explanations but also potentially neglecting certain relevant causal factors outside of a given module. For instance, in an economic model of national GDP, one could exclude the contribution of a particular industry or sector (say, the value of production in the textile industry) even if this industry does in fact contribute to overall GDP. Stabler (2011) describes the competence-performance idealisation of *Aspects* in a similar way. "That is, we aim to find domains with causal interactions that are relatively closed, domains that can be described relatively autonomously" (2011, p. 69). I argue that Government and Binding or GB (Chomsky 1981) can be described in terms of such a modelling strategy. In this theory, separate modules govern separate aspects of the syntax (and semantics). As before, the minimalist idealisations identify an even smaller set of properties (for maximum generality). For example, there are only three core levels of the grammar on this account, namely D-structure, S-Structure and Logical Form. S-structure is derived from D-structure and logical form in turn from S-structure. The latter derivation is governed by a single MOVE ALPHA transformation at both the D to S-structure level and the S-structure to LF level (as opposed to a vast number of separate movement operations in ST and EST).

Importantly, the GB framework distinguishes seven separate modules which govern or generate different aspects of the grammar, in line with the initial autonomy of syntax thesis (tenet 1 above). The phenomena in question might involve multiple modules interacting but are explained within their distinct causal modules (as in the hypothetical GDP case above). One important application of the government relation involves the notion of abstract case, such as nominative, accusative, dative and so on (considered to be a universal property common to all languages, although often unrealised in surface morphology). Governance (which is a relation between heads and their phrasal categories, involving the dominance relation of m-command) also interacts with theta-theory which encodes semantic and functional roles such as agent, patient etc. However, Case theory and theta-theory do not necessarily coincide, despite being related causal explanations for various phenomena. For example, in the Latin

[10] This is a somewhat more general account of "modularity" than is found in the canonical cognitive science literature, such as Fodor (1983) or Pylyshyn (1984). This is because modularity is posited as a genuine property of a system or set of systems. Hence the claims usually associated with it such as *domain specificity* and *inaccessibility*. Isolation, on the other hand, is an idealising technique used in the service of model-building.

[11] Mäki (2011) and Portides (2013) discuss isolation in models as well. Although their analyses involve conceptual omission or "screening off" of features of an actual system. They differ in that Mäki considers the isolation as a result while Portides considers it as a process within the model construction. In this way, my conception is closer to Portides'. I do not, however, include a conceptual act within my characterisation.

sentence below, both the theta-grid of the verb 'to give' or *dare* and the case of the indirect object requires/selects for a dative noun form of *Brutus*.

(i) Caesar Bruto dedit pecuniam. (Caesar gave the money to Brutus)

In GB these explanations are independent of one another. The idealisations of the theta-theory do not include those of the case theory, or rather they offer orthogonal minimal causal structures to explain the occurrence of the indirect object 'Bruto'. In GB, Chomsky describes the overall grammar in the following way (which exemplifies isolation idealisation).

> The system that is emerging is highly modular, in the sense that the full complexity of observed phenomena is traced to the interaction of partially independent subtheories, each with its own abstract structure (1981, p. 135).

Finally, the "minimalist program" or MP, as perhaps the name suggests, provides the most radical case of minimalist idealisation at work. MP is often described as a programme or approach as opposed to a distinct theory on the same level as GB or the Parallel Architecture. Within the terminology of this paper, perhaps the term "research tradition" might be more apt, although I think the framework dances on the line between tradition and programme at times.

> Minimalism isn't itself a *theory* of the language faculty that as such would or could compete with other such theories. No matter one's theoretical persuasion, a *minimalist strategy* of linguistic explanation is something one can choose to be interested in or not (Hinzen 2012, p. 95).

Thus, in many ways, MP is the canonical case of a modelling strategy as I have described it. In MP, we start our models with only what we "must take to be true" and then rebuild the system from this basis. Once again, we see the concept of *minimal determination* described in the previous section. In terms of isolation, MP maintains the generative tradition's separation between form and function (or competence and performance). In other words, the structure of the language faculty is independent of its communicative role. Furthermore, the communicative or functional aspects of the grammar are isolated from the formal features which have an alternative causal basis and role within a theory of grammar.

Previously we discussed Chomsky's notions of descriptive and explanatory adequacy. In MP, a level 'beyond explanatory adequacy' (also called 'natural adequacy') is introduced. The goal of linguistic theory now becomes to explain language as a "natural object" (in the sense of being bound by the biological and physical universe, as opposed to the mathematical and conventional ones).

> In principle, then, we can seek a level of explanation deeper than explanatory adequacy, asking not only what the properties of language are, but why they are that way (Chomsky 2004).

In MP, language is considered to be a perfect system, optimally designed in terms of "virtual conceptual necessity" or "general considerations of simplicity, elegance, and economy" (Chomsky 1995). Thus, the grammar (or narrow syntax) constitutes a perfect computational system *via* economy principles for syntax and semantics (economy

of derivation and economy of representation, respectively). In this way, Minimalism can be viewed as an account of what kind of models should be built in order to reflect the assumed design features of natural language (such as those above). Lappin et al. (2000) argue that both perfection and optimality are unclear notions in this framework and should constitute serious challenges to MP's adoption by those linguists working within the GB framework. In terms of my dialectic, the difference between GB and MP is especially illuminating.

> Throughout the modern history of generative grammar, the problem of determining the character of FL [faculty of language] has been approached "from top down" [as in GB framework]: How much must be attributed to UG to account for language acquisition? The MP seeks to approach the problem "from bottom up": How little can be attributed to UG while still accounting for the variety of I-languages [internalised language or specific state of the language faculty] attained, relying on third factor principles? The two approaches should, of course, converge, and should interact in the course of pursuing a common goal. (Chomsky 2008, p. 4).

Chomsky's distinction between "top down" and "bottom up" is not entirely clear. It can be, however, related to a topic in the theoretical physics and chemistry concerning what is referred to as "foundational" versus "phenomenological" approaches. The latter are the various frameworks such as GB, ST and the principles and parameters (P&P) which offer specific analyses of linguistic phenomena, what we have been calling research programmes. Foundational approaches, on the other hand, aim to answer the questions concerning the reasons behind the use or application of a given formalism. This might involve the search for a set of first principles which independently motivate the use of certain theoretical tools or explanations (i.e. questions at the research tradition level). Hinzen (2000) offers a comparative analysis of the minimalist program and the principles and parameters framework along these lines. He states, among other things, that minimalism attempts to rationalise rather than describe the phenomena under study. Furthermore, it aims to discover general principles underlying explanations and avoid overly technical solutions. GB can be compared to MP similarly. Whereas the GB framework approached the constitution of the common linguistic substrate or Universal Grammar by asking 'how much' structure needs to be innate, MP asks the question of 'how little' structure is needed. The operation of merge (as well as *select* and *move*), which takes two items and creates a labelled set containing both of these, is supposed to be the minimal requirement on the productive capabilities of the language faculty. Our complex model of natural language syntax now only involves a single operation which serves as the minimal causal basis for the entire system isolated from other potential causal factors (such as functional roles, the conceptual system etc.). There are some interesting ramifications of the merge postulate, both evolutionary and ontological. We will briefly return to some of the latter in Sect. 8.

In this section, I have claimed that the generative tradition in linguistics, from ST to MP, encompasses minimalist idealisation in the form of both minimal determination and isolation in the models of the various theories. I followed a Cartwrightian line in claiming that these techniques are indeed idealisations in terms of falsehoods not

only because the rules of linguistic theory pertain to highly idealised models but also because these models are taken to stand as placeholders for the true descriptions of a future neuroscience. I now move on to extending this analysis beyond generative grammar (narrowly construed) to other frameworks and the dynamic turn in syntax.

5 The dynamic turn and other frameworks

5.1 Other generative frameworks

Within the more broadly construed generative tradition in linguistics, we find many examples of both isolation and minimal determination, as I have described them above. Perhaps Jackendoff's parallel architecture (PA) serves as one of the best cases of both isolation and minimal determination and is therefore a useful starting point.

One of the aims of Jackendoff (2002) is to better integrate linguistics within cognitive science. In order to achieve this aim, he rejects a number of components of the Chomskyan view of generative linguistics, for instance the syntactocentrism, or the view that syntax is the central generative element of language. Jackendoff holds that this was a mistake. In opposition to this view, he proffers a parallel architecture of the language faculty.

> The alternative to be pursued here is that language comprises a number of independent combinatorial systems, which are aligned with each other by means of a collection of interface systems. Syntax is among the combinatorial systems, but far from the only one (Jackendoff 2002, p. 111).

He goes on to describe each independent rule-bound and hierarchical system in isolation from one another. This analysis includes a reconceptualisation of semantics as "a combinatorial system independent of, and far richer than, syntactic structure" (Jackendoff 2002, p. 123). Given this high level of modularity, we can glean a perfect case of isolation idealisation at work. Each system, phonological, syntactic and semantic, is generated by independent structures. Due to this modelling strategy, the interfaces between these structures become of particular importance in terms of a holistic concept of natural language. For an idea of how this works, consider the concept of the well-formedness of a sentence. Within the frameworks of the previous sections, the syntax determined the well-formedness of a sentence and the other steps in the derivation (phonological and semantic) were somewhat epiphenomenal (recall Chomsky's famous *Colourless green ideas* example which was meant to show grammaticality outwith interpretability). In the parallel architecture, the situation is different. A sentence is only well-formed if it is so within each separate system and there is a well-formed interface between them.[12] Burten-Roberts and Poole (2006) take issue with this aspect of the PA. They argue that trying to capture the structures

[12] Some of these interface principles or rules are constraint based, such as the head constraint (borrowed from HPSG) for the syntax-semantics interface or the required linear order mapping between phonology and syntax. There are also static idioms which bypass syntax entirely and occur between the phonological and semantic components.

of the modules independently results in a loss of the initial rationale behind those structures.

> The term 'semantic' [...] is relational. It suggests that the module is distinct from the central conceptual system in being dedicated to specifying the SEMANTICS-OF something expressions generated by the syntax, presumably. But this implies that those expressions have semantic as well as syntactic properties [...] Equally, a mechanism that specifies the semantics-OF syntactic expressions cannot be encapsulated with respect to syntax. Its rationale lies in syntax, being effectively 'interpretative' of it (as in models the PA claims to repudiate) (Burten-Roberts and Poole 2006, p. 622).

The complaint is essentially that the models of the PA neglect causally relevant material, i.e. part of what determines the semantic module is syntactic in nature or related to syntax. This, however, is consonant with my characterisation of isolation idealisation (in terms of falsehood). In this type of idealisation, causally relevant aspects are often ignored and false models are created for explanatory purposes. For now, it suffices to appreciate the isolationist modelling of the PA, whether it can retrieve the connections with syntax (through interfaces) or not is not our chief concern here.

Nevertheless, despite the differences, the parallel architecture does maintain the autonomy of syntax (and phonology and semantics) as well as the UG hypothesis (although Jackendoff takes pains to divorce the concept from misinterpretations in Sect. 4.2 of the book) and the competence-performance distinction (once again with some criticism of how the idealisation has "hardened" over the years).

Optimality theory (OT) is another approach in which minimalist idealisation is harnessed. Minimal determination is both an implicit and explicit device in OT. Explicitly, the formalism contains a GENerator which generates an infinite number of outputs or candidates for representation for each input of the grammar. The EVALuator component then chooses the optimal output from the set of outputs through a set of ranked, violable constraints or CON (in the sense that violations are permitted but those of higher level constraints count more than violations of lower level ones against the potential optimal candidates). CON is considered to be universal (in line with tenet 2). In terms of generative grammar, it possesses an assumption "that there is a *language particular* ranking of constraints from a universal set of constraints" (Blutner 2000, p. 190).

One reason for questioning the place of OT within generative linguistic modelling, as I have been describing it, is that it seems to be constraint-based as opposed to derivational or "generative" (in the proof-theoretic sense). It should be noted that GB also has a distinctive constraint-based flavour (more on model-theoretic syntax in Sect. 7). However, importantly as Smolensky (2001) notes, "OT has been formulated in both derivational and non-derivational or 'parallel' forms. Both variants are coherent expressions of the theory". The core idea in both cases can be explained in terms of minimal determination idealisation. The property of being an "optimal candidate" is generated directly by a universal set of inputs narrowed down by a minimal set of constraints. Blutner (2000) himself offers a bidirectional OT approach to semantics which is somewhat different to the generally unidirectional analysis of the generative

programme. Nevertheless, the key idea here is the minimal set of constraints. In OT phonology (where the framework received dominant status), the best analyses are the ones which generate a given typology of phonetic combinations *via* a minimal set of constraints and their relative rankings (see Hammond 1997; McCarthy 2003). In OT, there is no room for extraneous constraints. In fact, the methodology is essentially concerned with defining the fewest and often most specific constraints necessary for generating optimal candidacy.

I think that this should be sufficient to display the pervasive nature of minimalist idealisation through both minimal determination and isolation within the broader generative tradition. It might be objected at this point that there is major theory continuity within the frameworks so far discussed and perhaps the modelling practices can be more easily explicable in these terms. I do not think that this is necessarily the case. Cartwright et al. (1995) argue that theory and modelling are independent processes in the sciences. They argue that theories can serve as tools for models but are not to be defined by them. Unfortunately discussing this version of instrumentalism will take us too far afield, although in a similar vein to Cartwright et al., I will attempt to show, by example, that modelling practices can be held constant despite significant theory change. However, my method is the reverse of the one they take. While they argue that the London model of superconductivity underwent model change without theory change, I will argue that dynamic syntax utilises similar modelling strategies to the generative tradition while the theory has been shifted on almost all accounts.

6 Modelling dynamics

In this section, I hope to extend my analysis of the modelling strategies employed within the generative programme to a rival approach, namely dynamic syntax (DS). In so doing, I also hope to provide an account of the theoretical differences between these frameworks and their genesis in terms of the choices of minimal structures within the models as opposed to a shift in modelling strategies *in toto*. As previously noted, I will not be disputing the claim that DS marks a significant departure from the theory presented in generative grammar. For instance, the traditional competence-performance divide, representationalism and the autonomy of syntax are all unabashedly abandoned in this framework.[13]

In an attempt to account for both the deep context-dependence of natural languages and compositionality, DS roots its idealisations in the "dynamics of real-time language activities" (Cann et al. 2012, p. 359) where semantic factors inevitably affect any analysis. Tree structures do not represent hierarchical formal features or even word order in this framework but propositional content where nodes are not abstract syntactic

[13] DS does, however, possess a *sui generis* competence-performance distinction.

> As a result of this shift in perspective, the competence-performance distinction looks very different. Though there remains a distinction between the linguistic-competence model and a general theory of performance, the articulation of that competence model is no longer disconnected from the articulation of the latter. To the contrary, the competence model is developed on the assumption that it provides the architecture within which the choice mechanisms of performance have to be implemented (Cann et al. 2005, p. 25).

categories but compositional semantic concepts. Thus, there is no autonomous syntactic component and the idealisations of formal language theory (which were heavily reliant on the alleged connection between formal and natural languages) are jettisoned in favour of a model of incremental semantic growth in terms of underspecification and updates (in lieu of movement).

> This theory does not characterise the surface (constituent) structure of a sentence, but instead models the process of assigning an interpretation to a string of words in a left to right fashion. In other words, taking information from words, pragmatic processes and general rules, the theory derives partial tree structures that represent the underspecified content of the string up to that point in the parse (Cann 2001, p. 4).

For the point of illustration, let us return to the idea of well-formedness. We saw with generative syntax and the parallel architecture, there were two different but related notions of the well-formedness of a linguistic expression or sentence. In DS, the departure is more stark. Syntactic well-formedness is no longer the determining factor within the linguistic concept. For instance, in multi-person dialogues, certain sentences (or strings) can be plainly ungrammatical in isolation and yet give rise to well-formed structures.[14] Consider the example from Cann et al. (2012, p. 365) below:

> Father: We're going to Granny's.
> Mother: to help her clean out her cupboards.
> Child: Can I stay at home?
> Mother: By yourself? You wouldn't like that.

Various traditional locality requirements on pronouns or anaphors (such as *yourself*) are violated in this exchange and yet it is unproblematically interpretable and natural. Thus, the models of DS are built up from a basis that goes beyond the single-person and sentence level boundaries of the previous frameworks which we have discussed. In addition, the formalism acknowledges the word-by-word contribution within expressions and not only the final output of a derivational process (in this way following the path of unification-based grammar formalisms such as GPSG and HPSG etc.). "The way this is achieved is to begin from a goal associated with some very partial structure and progressively enrich that structure through the parse of a string of words" (Cann et al. 2005, p. 33). Various techniques from semantics and dynamic semantics, such as underspecification and updates, are incorporated in order to accomplish this analysis.

The usage-based (parsing) elements of this formalism take it further from the abstract rule-based representationalism of the generative programme toward a characterisation of linguistic knowledge as a type of "know-how", i.e. knowing a language involves knowing how to use it. Thus, it seems as though the models of DS are vastly different from those of the generative programme and indeed, in some respects, they are. However, in terms of the type of modelling employed by practitioners within this

[14] Although the notion of 'string well-formedness' is not part of this approach (i.e. there is no 'membership problem' in the Turing sense), the idea of a well-formed or 'complete' utterance is present (on the basis of which grammatical judgements are made). "We may take the concept of 'complete utterance' in some language L to be one for which it is possible to construct a propositional tree of type t from an uttered string of words using the lexical, computational and pragmatic actions licensed in L (Cann et al. 2005, p. 398).

framework, I think some important continuity can be found. Primarily, I hope to show that DS does employ a minimalist idealisation approach to its models.

In order to see the modelling continuity, let us revisit the motivations behind some of the aspects of the theory change in DS. One of the leading motivations behind DS (and the dynamic turn in linguistics in general) is the apparent failure of static accounts to deal with phenomena such as ellipsis, anaphora and tense. In other words, the objection is that by focusing the minimal models on a static sentence and single person boundary, the generative programme (and other approaches) has failed to capture the property of interest in these cases, i.e. acceptibility judgements of speakers in many of the cases involving dialogue data etc. Furthermore, ignoring such data as performance error or dysfluency is claimed to result in incomplete models as well as only a partial approach to the language acquisition problem (or the 'explanatory adequacy' of the generative programme) since young children are confronted with such data on a daily basis and it is systematic. "The effect [of ignoring the aforementioned data] will be that no single linguistic phenomenon will receive a complete characterisation" (Cann et al. 2012, p. 367).

Thus, the problem is not with the technique of minimalist idealisation but rather with the starting point. In order to account for the complete desired property or phenomenon, for instance anaphora in English, we need to consider a different minimal model, such as the discourse level or dialogue data. The modelling strategy remains constant in this case, e.g. minimal derivations in trees and operations on trees. DS modelling merely starts its idealisations from a different place but still aims to determine the property of interest (grammaticality or anaphoric binding) in a minimal way.

> In making such a move into explaining what have been deemed to be structural properties of language in terms of the ongoing process of building up interpretation, there will have been a substantial shift in our assumptions about the basis of syntactic explanations (Cann et al. 2005, p. 19).

The resulting model retains many structural features such as tree structure and operations thereon (such as substitution and adjunction) as well as theoretical features such as simplicity as *per* minimalist idealisation.

> In contrast to standard and static approaches, we shall see that the time-linear perspective of Dynamic Syntax allows an entirely natural set of analyses of these phenomena using the same concepts of tree growth, while preserving incrementality of parsing. In addressing these and other current puzzles, our claim in each case will be that the model we set out will be uniformly simpler than other more conventional models that are designed not to reflect the time-linearity of natural language processing (Cann et al. 2005, p. 25).

I think that *isolation* might be somewhat harder to establish as most DS models are quite integrative. Nevertheless, there are aspects of the theory which display isolationist modelling tendencies. For instance, the semantic typing system (a modified version of Montague grammar) is defined separately from the modal logic definitions involved

with the tree formalism which is a variant of the Logic of Finite Trees (Blackburn and Meyer-Viol 1994).[15]

In DS, linguists are still in the business of developing minimal models and attempting to "generate" (in the sense of minimal determination) the properties or explanations thereof by offering a causal basis which ignores even potentially relevant or related material. The framework might seem to aim for "completeness" but this completeness should not be confused with completeness at the initial modelling stage. In other words, the models aim to account for phenomena such as anaphora, ellipsis, quantifier scope etc. in a more complete way than their predecessors (of the generative persuasion) but they aim to do so through the most economical means possible (replete with the gamut of *ceteris paribus* modifiers and the like). For instance, underspecification plays an important role in the theory. This is a technique used to represent or generate multiple semantic (or other) representations within a single representation. Underspecification is a common technique for dealing with a wide range of ambiguities (both lexical and structural) in natural language semantics (and processing), without necessarily altering anything at the syntactic level.[16]

Semantic underspecification is basically an intentional omission of linguistic information from semantic description. The underlying idea is to postpone semantic analysis until it can be executed in such a way that various ambiguities can be resolved. This is accomplished by producing a single representation capable of representing multiple realisations. In other words,

> The key idea of underspecification is to devise a formalism which allows to represent all logical readings of a sentence in a single compact structure. Such a formalism allows one to preserve compositionality without artfully casting pure semantic ambiguities into syntactic ones. (Lesmo and Robaldo 2006, p. 550).

This process amounts to a type of storage of interpretations without immediately checking for consistency. At a later stage these interpretations are pulled out or extracted and interpreted in parallel. A given semantic representation can be underspecified in one of two ways.

1. Atomic subexpressions (constants and variables) may be ambiguous, i.e. do not have a single value specified as their denotation, but a range of possible values;
2. The way in which subexpressions are combined by means of constructions may not be fully specified (Bunt 2007, p. 60).

These paths specify constraints on representations of meaning and are often viewed as meta-representations which display all the representations that satisfy the set of constraints, i.e. all the possible readings of an expression.

Consider the following classical example of semantic underspecification in terms of scope ambiguity. It is well-known that sentences such as *Every linguist likes some tree* have at least two readings, one in which each linguist in the relevant domain is fond

[15] I thank an anonymous referee for pointing out the potential modularity of the DS framework at the metalinguistic level.

[16] For instance, representing the scope ambiguities through alternative syntactic derivations can lead to an explosion of ambiguity and the need for innumerable alternative syntactic configurations. See Bunt and Muskens (1999) for a proof of this based on the ambiguity in an average Dutch sentence.

of one specific tree (existential) and another in which there are many trees which are liked by many linguists (universal). One could account for these alternative readings by means of compositional semantic rules defined over distinct syntactic derivations. This is the Montagovian route. Or one could represent both (or all) readings in one structure *via* underspecification. We will follow Bos (1996) and Blackburn and Bos (1999) in defining a simple Hole Semantic framework (I have simplified the framework considerably, for the sake of illustration).

For this task we need two new tools, labels and holes respectively. Labels $\ell_1, \ell_2, \ldots, \ell_n$ are associated with each element of the set of expressions E_U. If a label ℓ_1 consists of two subexpressions which are joined by a construction k, then $\ell_1{:}\,k(\ell_2, h_1)$ where ℓ_2 is the first of subexpressions and the second is an unknown entity called a hole "i.e. a variable that ranges over the labels of the subexpressions in E_U" (Bunt 2007, p. 64).

The HOLE variables are plugged (or glued or resolved) by means of operations which replace the holes with subexpressions. The procedure is as follows. Labels are our constants and holes are the variables over these constants conceived as arguments over certain operators which possess scope. Constraints are defined in order to reorganise the elements in such a way that they cover every possible reading of a given sentence.

Then, we have our pluggings (which are one-to-one mappings from holes to labels). "A plugging is a bijective assignment function, with the sets of holes as scope and the set of labels as range" (Bos 1996, p. 135). The pluggings can be represented by an object language such as intensional logic or tree structures with lambda expressions as in DS or whatever. Consider the sample sentence again:

Every linguist likes some tree.

The underspecified representation will look something like the tuple below:

$$\left\langle \left\{ \begin{array}{l} \ell_1 \\ \ell_2 \\ \ell_3 \\ h_0 \\ h_1 \\ h_2 \end{array} \right\}, \left\{ \begin{array}{c} \ell_1 : \forall x(Linguist(x) \rightarrow h_1) \\ \ell_2 : \exists y(tree(y) \wedge h_2 \\ \ell_3 : LIKE(x, y) \end{array} \right\}, \left\{ \begin{array}{l} \ell_1 \leq h_0 \\ \ell_2 \leq h_0 \\ \ell_3 \leq h_1 \\ \ell_3 \leq h_2 \end{array} \right\} \right\rangle$$

There are three components to the above representation. On the left, we have the inventory of labels and holes or set thereof. In the middle, we have what Blackburn and Bos (1999) call "PLU-formulas" (or Predicate Logic Unplugged formulas defined in the usual way in terms of the syntax of PL). On the right, we have our set of constraints on scoping relations.

In order to retrieve the readings, we introduce variables h_0 for "widest scope" and h_1 for "narrow scope". Firstly, in defining the constraints, we would want $linguist'$ to be under the scope 'every', i.e. $\ell_1 \leq h_0$, and $tree'$ to be under the scope of 'some', i.e. $\ell_2 \leq h_1$. Then, obviously we would also want $\ell_3 \leq h_2$ and $\ell_3 \leq h_1$ or "the basic PLU-formula $[LIKE(x, y)]$ is forced to be outscoped by the consequent of

the universal quantifier's scope, and the second conjunct of the existential quantifier's scope" (Blackburn and Bos 1999, p. 86). Hence, there are two pluggings available:

$$P_1 : \{\ell_1 \leq h_0, \ell_2 \leq h_1, \ell_3 \leq h_2\}$$
$$P_2 : \{\ell_2 \leq h_0, \ell_3 \leq h_1, \ell_1 \leq h_2\}$$

The two pluggings correspond to the two possible readings for the quantified sentence, the first is the reading in which the universal has wide scope, i.e. in which multiple trees are liked, and the second is the reading in which the existential has wide scope, i.e. there is one distinct tree liked by all. Scope itself is the underspecified content in this representation. In DS, one kind of underspecified content takes place at locations in trees which through the operation of adjunction (borrowed from Tree-Adjoining Grammar) can be fixed to unfixed nodes. So the tree structures have underspecified branches (usually represented by dashed lines) and can be fixed to different nodes for the purposes of either anaphora resolution or other tasks.[17]

The overarching point is that semantic underspecification is a means of capturing multiple meanings within a single structure and a clear example of a minimalist idealisation. Underspecification is essentially misrepresentation for the sake of disambiguation or resolution at a later stage in the process. The rules of the grammar then apply to this idealised compact structure. Many of the other techniques utilised in DS are similarly motivated and closely aligned to simplicity considerations. The framework (non-trivially) exploits the strategy of minimal determination, as I have described in the previous chapter. In this way, it is within the modelling paradigm of the broader generative tradition in linguistics despite theoretical differences.

7 Model-theoretic syntax and overgeneralisation

Before concluding, I think it expedient to address a potential objection. One potential concern when offering accounts of modelling in linguistics (and the sciences in general) is the overgeneralisation of explanation. In describing a phenomenon which admits to certain vague or imprecise notions such as 'causality', 'minimal', 'determination' etc., a theorist can often provide explanations which trivially capture too much (or everything) and thus fail to distinguish between relevant alternatives. If all of linguistics from Hockett's finite grammar to Smolensky's harmonic grammar or Croft's radical construction grammar could be explained in terms of minimalist idealisation, it would be no surprise that dynamic syntax followed suit. Fortunately, I believe that this is far from the case. In what follows, I will briefly mention some linguistic frameworks (or families of frameworks) which I believe do not have minimalist idealisation at their core. Once again, it is in no way my claim that minimalist idealisation is a preferable modelling strategy. I take no position on the fecundity of one type of modelling over another, my project is merely a descriptive one. I should also note that this analysis is not meant to be exhaustive. Many frameworks, including generative grammar, can

[17] DS also makes use of "formula underspecification" more redolent of traditional accounts such as Cooper Storage in which formulas are replaced with underspecified content (or semantic representations acting as placeholders for lambda terms). Even the X-bar schemata of Sect. 4.1 can be considered underspecification albeit of a different nature to the semantic underspecification discussed above.

and do involve other forms of modelling and idealisation. My claim is that minimalist idealisation is at the centre of many of these frameworks, not that it is the only strategy used to model linguistic reality within them (or to theorise more generally).

As I have mentioned, there are some similarities between both the parallel architecture and DS to model-theoretic approaches to grammar, I think that this would be a good point at which to describe these non-minimalist idealisation approaches. In Pullum and Scholz (2001) and Pullum (2013), the notions of generative-enumerative versus model-theoretic syntactic formalisms are discussed and teased apart. The former are related to the formalisms discussed in the previous sections (with the exception of DS which has elements of both). These formalisms drew inspiration from the syntactic (or proof-theoretic) side of mathematical logic (and Post's work on the subject). However, model-theoretic approaches were developed from the semantic side of logic and diverge from the generative-enumerative approach significantly. In this way, I think that model-theoretic syntax idealises its models in a distinct way as well, i.e. not *via* minimalist idealistion.

One of the core technical notions of the previous formalisms was that of "generation" in the 'recursively enumerate' sense of defining a device with a finite set of rules capable of generating an infinite set of sentences/strings/structures. On the contrary "[a]n MTS [model-theoretic syntax] grammar does NOT recursively define a set of expressions; it merely states necessary conditions on the syntactic structures of individual expressions" (Pullum and Scholz 2001, p. 19). Think of this approach in terms of model-theory. A sentence is well-formed iff it is a model of the grammar (defined in terms of constraints which act as the axioms of the formalism). To be a model of the grammar is to be an expression which satisfies the grammar (meets the constraints). Consider the first-order analogy. To be a model of arithmetic is to satisfy (or make true) the axioms of arithmetic (Peano or others). There are nonstandard models of course and Gödel's famous incompleteness result showed that there can never be a complete axiomatisation of arithmetic (i.e. no system will be able to capture all the truths of arithmetic). The point is that the idea of "being a model" of a grammar in this sense is quite divorced from the idea of "being generated" by a given grammar.

Formalisms such as generalised phrase structure grammar (GPSG) and head-driven phrase structure grammar (HPSG) are examples of this constraint-based approach.[18] Some differences between the approaches involve concepts such as set cardinality. In Sect. 4. we saw the motivation behind early generative grammar was to capture the notion of linguistic creativity described in terms of discretely infinite output. This is a corollary of the generative-enumerative approach, i.e. generative grammars generate or produce a fixed number or set of expressions (the upperbound is $\aleph_0$ or the cardinality of the natural numbers). Contrary to this, model-theoretic or constraint-based grammars do not impose such size-limits and are generally non-committal in terms of cardinality (which is not to say that they cannot account for creativity). The core of idea of

[18] Although in the introduction of their textbook, Sag et al. (2003) speak in generative terms about the purpose and nature of grammar. "Thus we will again and again be engaged in the exercise of formulating a grammar that generates a certain set of word strings—the sentences predicted to be grammatical according to that grammar" (2003, p. 21). They also stress the importance of capturing the infinite set of expressions of natural language (through Kleene star operations and the like).

specifying the least amount of rules for the most amount of structural description is thus jettisoned in favour of listing as many constraints as the multifarious features of language seems to dictate.

Now, there is certainly a parallel between specifying a set of axioms or constraints in defining a grammar and specifying a set of rules in generating one but the latter approach is more in line with minimalist idealisation than the former for important reasons. There are other significant differences, but I shall focus on those that involve (or result in) a shift in modelling practices. We have already seen that the concept of infinity generation is abandoned on the model-theoretic approach but another important (relevant) departure from minimalist idealistion is the level at which the models are defined. For frameworks within this paradigm, models are individual expressions, not sets of such expressions. In the generative programme, for the sake of generality, there was a movement towards categories (as sets) of expressions and rules involving these categories (recall the X-bar rule schemata in Sect. 4.1). Model-theoretic accounts, on the other hand, quantify over specific expressions and the structures relating to these expressions.

> For example, if trees are the intended models, quantifiers in the statements of MTS grammar range over a set of nodes, not over a set of trees (Pullum and Scholz 2001, p. 23).

There are some important consequences of this feature of model-theoretic approaches. They all seem to be related to the greater specificity or accuracy which they allow the grammar to express or capture. For instance, expression fragments can more readily be treated under this framework. These could be fragments with syntactic structure or information (and semantic or phonological as well) that are not strictly grammatical [such as *and of the* example in Pullum and Scholz (2001)] and thus would not be generated by a generative grammar. By focusing on individual expressions we can also capture the use and proliferation of neologisms and the lexically creative aspect of natural languages. Given that the lexica of various languages are constantly changing, a formalism (or family of formalisms) which can capture (or at least not make bad predictions) about such expressions would be useful.[19]

There are a number of other such differences related to models as individual expressions. Some linguists (within the probabilistic school) have been claimed that the generative-enumerative approach can be described as "prescriptive" in the pejorative "grammar school" sense from which linguists have taken pains to separate themselves. There are constructions and phrases that pop up all over human language (and corpora) that would be deemed simply ungrammatical in the generative sense (i.e. not generated by any rule).[20] Manning (2003) identifies one such construction, namely

[19] Both language fragments and neologisms can be captured by the incremental word-by-word parsing formalism of DS in a generative-enumerative way. In addition, some interpretations of Minimalism might also have the resources to deal with these phenomena.

[20] This is related to the motivation behind DS and its claim that generative grammars offer incomplete descriptions since they miss out on relevant and systematic data found in corpora and multi-person discourse. However, traditional GB/Minimalist accounts in terms of 'ellipsis' might work as well for many of these cases.

as least as. This construction sounds strange at first glance but does seem to appear across various texts. Manning (2003) claims that generative grammar (which he calls a "categorical linguistic theory") is prescriptive in the sense that it places hard boundaries on grammaticality when these boundaries are much fuzzier in reality. I think that the point misinterprets the modelling strategies, such as minimalist idealisation, at the heart of the generative models discussed above. Unfortunately, the probabilistic linguistic models Manning suggests in their stead are beyond the current scope of discussion. Importantly, however, the criticism is related to the model-theoretic approach and its method of idealisation. In one way, generative grammars idealise too little (as *per* minimalist idealisation) and, on the other, they overgenerate (due to the lack of specificity). Thus, there is a need for theta-grids and other ways of narrowing down the grammatical output of the grammar in generative frameworks such as Government and Binding.

Constraint-based grammars focus on individual expressions and their satisfaction of certain sets of constraints. In so doing, they not only move away from the idea of minimal transformational derivation, but also admit for increased specificity at the individual expression level and in turn at the initial model level. The model aims to admit and satisfy as many constraints as needed to encode syntactic, semantic and other information, in order to characterise grammatical well-formedness. However, the descriptions involved in the models of the grammars can be quite complex. In fact, the models or expressions can be infinite in length on the constraint-based view (a welcomed feature for adherents of Langendoen and Postal's (1984) "vastness" result). Whereas in generative grammar this is not the case (without significant modification of the notion of "generative" or "derivation"). This is another advantage of the MTS framework according to Pullum and Scholz (2001).

So our base case could begin with a potentially infinite model (expression) with a multitude of constraints (all well-motivated of course). With the development of the generative programme in Sects. 4 and 4.2 we saw a progression toward generality and the exclusion of (even causally relevant) material, in the model-theoretic framework of constraint-based approaches we see the reverse and a progression toward specificity and the inclusion of more information, some of which is causally relevant material, others not necessarily so (e.g. there might be irrelevant phonological information for instance). In addition, these approaches tend not to be modular or make use of *isolation* idealisation. For instance, feature structures, which can be modelled as functions from sets of features to values (or valences), in HPSG, are used to model grammatical categories as information structures. These structures can be extremely complex (as anyone who has used or seen a tree in HPSG can attest). The inclusion of semantics introduces additional information and structure into the features structures.

> The richer feature structures we are now using, together with our highly schematized rules, have required us to refine our notion of how a grammar is related to the fully determinate phrase structure trees of the language (Sag et al. 2003, p. 167).

To close off this sketch, let us consider a basic operation in the grammar, namely unification. This operation takes two feature structures and creates one that contains

all the information (and constraints) of both (as long as it is not inconsistent). Thus we are building larger and larger information structures into the scientific models of the grammar. I think we have moved quite a distance from minimalist idealisation and the modelling practices that come with it. One aspect of minimalist idealisation is that de-idealisation is very often not possible, recall the Ising model of ferromagnetism mentioned in Sect. 4 in which particles are represented simply as points along a line. Feature structures and model-theoretic syntax allow for gradability of representation and the re-introduction of removed material. To be more specific, in formal language theory, sentences are modelled as semantically vacuous strings. A grammar, as a generative device, specifies the types of rules applicable to these strings in order to generate different sets of strings, i.e. languages, of varying complexity. For example adding recursive rules to the rules which generate regular grammars gives rise to context-free grammars and so on (this picture is overly simplistic for the sake of illustration). Given this idealisation, there is simply no room for semantic content or phonological character to enter into the resulting model. These aspects of language are dealt with separately (in line with isolation idealisation). Contrasted with this, in constraint-based or model-theoretic approaches we can admit as much information into the base syntactic feature structures as we like, including semantic and phonological features. The models are not incompatible with introducing more and more information or features in order to "come closer" to the real world target system. This is the hallmark of *Galilean idealisation* (or mere abstraction) as (Weisberg 2007, 2013) describes it or distortion for the sake of computational tractability with the possibility of reintroduction of abstracted or idealised material. However, this is generally not a feature of minimalist idealisation.

8 Why models?

As previously mentioned, an assumption prevalent in this research is that grammar construction in linguistics is a type of modelling or indirect representation. There are various benefits of adopting this perspective, I will focus on two such reasons here, one from the philosophy of linguistics and the other related to issues in the philosophy of science more generally.

8.1 Infinity, recursion and modelling

The first issue concerns the alleged "incoherence" of the generative programme in linguistics. It has been claimed, by Katz, Postal and others, that on the one hand generative linguistics has an unifying scientific agenda in that linguistics is supposed to be the study of the language faculty conceived of in mentalist and thereby physicalist terms (or at least post-*Aspects* generative grammar). Grammars describe I-languages or cognitive states of the language capacity corresponding to the various rules of specific languages. On the other hand, linguistics maintains that strictly formal aspects such as discrete infinity and the set-theoretic operation of merge are essential to the description of natural language. The latter aspects are held so strongly that discrete infinity is often

claimed to be the single most significant component of the language faculty narrowly construed (i.e. an explanandum as opposed to an idealisation) (see Chomsky et al. 2002).

> The received view claims that an NL is something psychological/biological […] a state of an organ […] And yet it has been unvaryingly claimed in the same tradition at issue that NL is somehow infinite. These two views are not consistent (Postal 2003, p. 242).

If we accept that linguistic grammars, which contain "infinity yielding" operations such as merge, are indirectly related to the target system of natural language, then the worry evaporates. Models do not commit the physical world to their properties any more than a physical model of DNA commits the molecular structure of living organisms to Styrofoam or plastic constitution. In other words, the usefulness of a model does not require that every property of the model be a property of the system being modelled. Models need only resemble the target system and as we have seen this process does not always involve veridical representation, i.e. is not *directly* ontologically committing to the target system. For instance, Tiede and Stout (2010) offer a similar analysis of generative grammars.

> It is clear that to the extent that linguistic theories, i.e. grammars, aim to capture human knowledge of language, these theories are formal models. In fact, grammars in the generative tradition are symbolic models, as opposed to, say, connectionist models or dynamical systems (Clark 2001). The fact that generative linguistics employs symbolic models has a crucial impact on the role of recursion and infinity (147).

They go on to claim that linguists are not committed to natural languages being discretely infinite just because recursion is a feature of our generative grammars. Thus, discrete or denumerable infinity is assumed or a "modelling choice" on their view and not a feature of the target system as both generativists and platonists, such as Postal, claim. Furthermore, as shown in Pullum and Scholz (2010), recursive rules do not guarantee infinite structures or structural descriptions, "[a] generative grammar can make recursive use of non-useless symbols and yet not generate an infinite stringset" (120).[21] Nor for that matter does linguistic infinity require recursion, as Tomalin (2007, pp. 1797–1798) notes "if the sole requirement is to generate an infinite number of structures using finite means, then an iterative, rather than a 'recursive', process could accomplish this, and while such a procedure may be less efficient than a 'recursive' procedure, the basic point is that a requirement for infinite structures using finite means is not itself sufficient to motivate the use of specifically recursive procedures."

[21] The recursive rule they use to show this is $VP \rightarrow VP\ VP$ in a simple context-free grammar for the sentence *They came running* which generates only two structures *They came* and *They came running*.

Even if we do not accept Postal's challenge (as many linguists are wont to do),[22] we still need to account for the nature of operations such as merge or other recursive constructions within natural language and whether or not they should receive physical instantiation. Accepting that grammars are models (in the scientific sense) enables theorists to avoid debates as to the universal nature of these operations and the plethora of claims to the contrary.

8.2 Structural realism and linguistics

The next reason for the present modelling perspective stems from the philosophy of science more generally. When caught between the pull of realism and the rational scepticism of anti-realism, structural realism has often been considered a happy medium (the "best of both worlds" strategy). I want to sketch some of the reasons for opting for this alternative (coupled with a modelling interpretation) within the context of linguistic theory.

It is well-known that traditional realism in the philosophy of science faces a serious challenge often referred to as pessimistic meta-induction or the problem of radical theory change. This problem relates to explaining progress in science. If our theories are true of the world (or even approximately so), then how can we explain scientific progress in cases in which theories have radically altered (as in the move from Newtonian to Relativistic physics)?

One answer to these sorts of worries is scientific anti-realism. On views under this framework, scientific theories need only be empirically adequate (get the observables right). Van Fraasen (1980) is one case of this view. Interestingly, this latter work has led to much of the focus on modelling in contemporary philosophy of science. Although this might be a viable option, it does lead to similar worries to that of instrumentalism in rendering the success of our models or grammars inexplicable (or miraculous). There is, however, a more modest alternative in views under the banner of structural realism. As Ladyman (1998) puts it,

> Rather we should adopt the structural realist emphasis on the mathematical or *structural* content of our theories. Since there is (says Worrall) retention of structure across theory change, structural realism both (a) avoids the force of the pessimistic meta-induction (by not committing us to belief in the theory's description of the furniture of the world), and (b) does not make the success of science […] seem miraculous (by committing us to the claim that

[22] Postal (2009) briefly addresses and dismisses a related line of argumentation. He claims that understanding "infinite generation" or "recursion" as idealisations of some sort is to illegitimately equivocate on the terms 'idealisation' and 'recursive'. As opposed to the idealisation of say a frictionless plane in physics, this idealisation is more close to "one which claims the solar system has an infinity of planets" (2009, p. 110). However, I would argue that if such an idealisation were useful to a physicist or astronomer or helped understand some other property of the solar system, then it would be a perfectly acceptable aspect of a model (statistical cosmology is full of such idealisation). See Morrison (2015) for a number of examples involving the simplifying assumption of infinity in particle physics and population genetics. See Savitch (1993) for an account of how viewing natural languages as "essentially infinite" (even if they are only largely finite) might involve simplicity considerations similarly.

> the theory's *structure*, over and above its empirical content, describes the world) (410).

Contemporary linguistics faces a similar situation to that of the various paradigm shifts in the history of science. The dominant tradition, or rather specific theories under the programme of generative grammar, is under increased scrutiny and alternative frameworks such as Dynamic Syntax, HPSG, and Construction Grammar abound. Understood in structural realist terms, this does not entail abandoning many of the insights or successes of the former. Linguistics, like the natural sciences, does not begin *de novo* with every theory change, if we maintain the continuity of *structure*. Seen in this light, the previous sections argued for structural relations or similarity between not only different strains of the generative tradition but also across other frameworks such as DS.[23]

The structures in question are the mathematical models of the theories or the grammars.[24] In Weisberg (2013), he describes a third kind of model besides the concrete and mathematical ones, namely computational models. To a certain extent, it is not clear how distinct computational models are from mathematical models (as Weisberg seems to admit when pressed). Nevertheless, computational models have a distinctive procedural or algorithmic element. This aspect allows them to track or represent the dynamics of systems (in terms of states and transitions between them). The models of generative grammar (and dynamic syntax) are of this variety according to most of its practitioners. This might turn out to be no more than a convenient parlance, further reducing the lines between mathematical models and computational ones in linguistics. As Pullum (2013) notes

> The fact that derivational steps come in a sequence has encouraged the practice of talking about them in procedural terms. Although this is merely a metaphor, it has come to have a firm grip on linguists thinking about syntax (Pullum 2013, p. 496).[25]

The model in DS still involves tree structures and relations between nodes but it extends this analysis beyond the features of the generative picture with a genuinely

[23] There is precedent for the extension of the structural realist analysis beyond the natural sciences. See Kincaid (2008) for such an account for the social sciences.

[24] Taking the models themselves to be the structures of a structural realist account is also not unprecedented. On Morgan and Morrison's (1999) account, models are (partially) independent of theory and the target system as discussed above. Autonomy of models is also argued for in Suárez and Cartwright (2008) with relation to the Londons' model of superconductivity.

[25] If we do take the metaphor seriously though, we might be tempted to describe another underlying difference between derivational and non-derivational or model-theoretic grammars, in that the former and not the latter can be considered to be computational (where computational is understood as a proper subset of mathematical models). Chomsky (2000, pp. 98–100) seems to have something similar in mind when he discusses the difference between the *derivational approach* and the *representational approach*, the former is meant to be understood as a genuinely algorithmic construal of the brain's actual design *vis-á-vis* generating linguistic expressions and the latter is to be understood as a "direct recursive definition" or conditions on expressionhood (as in the model-theoretic case). Despite claiming that the differences might be overstated or merely intertranslatable, he goes on to adopt a derivational approach under the assumption that it does hold unique insights into language (and additional questions concerning it). The present work can be seen as an account of wherein this difference lies exactly, i.e. modelling strategies.

procedural aspect. For instance, we have seen (in Sect. 6) that the model base in DS also includes multi-person dialogues. Importantly, extending the standard generative models in line with GB and other frameworks is also possible and would then cover the same data i.e. be empirically equivalent (see below for an example). Thus, the idealisations would be similar (operations and relations on trees), both would involve procedural computational models and both would cover the same data (as opposed to say the "flat structures" of dependency grammars). The idea, of course, cannot be that the models are identical since they are not, but rather the claim is that generative grammar and dynamic syntax make use of similar structures, here conceived of as families of computational models. Cann et al. are illuminating this point.

> [W]e take the concept of a TREE STRUCTURE familiar in syntax and use it to represent, not structure defined over words in a string, but the interpretations assigned to words uttered in context (Cann et al. 2005, p. 32).

The above situation is similar to the case of the Londons' model of superconductivity. The previous model was considered to be limited in explanatory power and scope. For instance, it could not account for the Meissner effect, which is the expulsion of magnetic fields from superconductors during the transition to the superconducting state. In order to account for this effect, the Londons took superconductors to be diamagnets as opposed to ferromagnets, a modelling choice independent of theory [or so it is argued by Suárez and Cartwright (2008)]. In the same way that the Londons' model is claimed to have borrowed piecemeal from other models and theories, DS too borrows from other models, some generative and some model-theoretic, and theories, some static and others dynamic, in order to account for anaphoric relations beyond the sentence and person boundary. The model structure or scaffolding (*via* trees and relations and constraints on subtrees) remains constant. By appreciating the concept and use of models, we gain a clearer picture of theory change and theory comparison which helps to forge a closer tie with the structural realist position in the philosophy of science and thereby provides potential answers to the questions of progress and change in linguistics.

This situation is, however, dissimilar from some of the usual conclusions drawn from the recent flurry of formal proofs as to the *weak equivalence* of various grammar formalisms (i.e. they generate or produce the same sets of expressions/sentences). The idea is that minimalist syntax (MS),[26] phrase-structure grammars (PSG), tree-substitution grammars (TSG), head-driven phrase structure grammars (HPSG) and dependency grammars (DG) are all really just "notational variants" of one another with little empirical consequence [as in Chomsky's (2000) example of $25 = 5^2$ vs $5 = \sqrt{25}$]. To a working linguist *qua* modeller, I argue, these proofs mean little to nothing. For instance, dependency grammars posit structural relations which differ significantly from phrase-structure grammars (in fact, DG is flat structurally as opposed to hierarchical, i.e. argument form trumps dominance relations). Similarly, TSG's lack a mechanism for deriving rules such as adverbial modification (easily specified in PSGs) since they do not possess an adjunction operation as in later Tree-adjoining

[26] Or rather Stabler's (1997) interpretation thereof.

grammars. Yet many of these formalisms can be shown to be weakly equivalent. As Rambow and Joshi (1997) note, these equivalences are of little consequence to the syntacticians working in a given syntactic framework who still go about their daily business in very different ways. "The result is a dependency tree, CFGs and TSG are weakly equivalent. However, to a linguist, they look very different" (Rambow and Joshi 1997, p. 3). Again, by appreciating the roles and operations of the models themselves, we can arrive at a more nuanced account of theory similarity and dissimilarity in linguistics, as I hope to have shown.

Thus we can be realists about the structures indirectly picked out by the models and at the same time be instrumentalists about the models themselves. Also, in light of what we have seen in this paper, theories cannot just be collections of models, since we have seen that models operate in partial autonomy from theories. Models, however, could still inform theory construction. Cases such as Dirac's discovery of the positron, in which an assumed artifact of the model was found to be ontologically significant to the target system, show that it is possible that the structures indirectly represented by models can eventually be described directly by theory.[27]

By way of example, consider briefly binding in both generative grammar and dynamic syntax. I hope to show that the analysis along the lines of generative grammar is similar to that of DS structurally.

Binding is a relation which holds between anaphors and antecedents (indexed below) within what is called a *binding domain*.

3. Mary$_i$ mentioned that she$_i$ was excited about linguistics.

In this case, *Mary* is said to bind *she*. In the generative literature, the binding domain or the linguistic environment which licenses binding is the sentence (or the TP in some cases). This model of anaphora could have various initial limitations. For one thing, as we have seen, it is focused on the sentence and single person boundaries. Another aspect of the analysis is that given that binding is usually constituted by a dominance relation on nodes in trees (c-command), order (in the tree) becomes important. A favourite construction of dynamic syntacticians is a type of long-distance dependency called "left-dislocated" expressions as in the examples below modified from Cann et al. (2005, pp. 167/170).

4. Mary, John thinks Tom had upset.

5. Mary, she I think isn't coming.[28]

If binding is governed by c-command which holds only between mothers and daughters in trees, then (4) and (5) are rendered infelicitous (they contravene Condition B in traditional GB binding theory). Nevertheless, there are many modifications of the

[27] Dirac initially thought negative energy solutions were merely features of the mathematical model and not physically realised but later, after finding physical interpretations of them, he revised his theory which led to the prediction of the existence of a novel particle, the positron. See Bueno and Colyvan (2011) for further discussion.

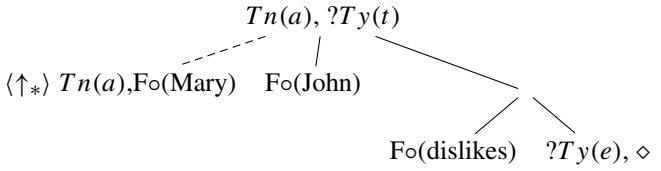
[28] If the examples seem unnatural in English, cross-linguistic evidence attests to the phenomenon more broadly. For instance, in the German construction *Den Peter, den habe ich gesehen.* (I saw Peter) (Ott 2014, p. 269) and many other cases.

standard theory which do aim to account for long-distance dependencies such as those mentioned above. These accounts are usually couched in terms of movement and traces (see Wiltschko 1997; Zaenen 1997). Frey (2004), following Cinque (1990), posits a quasi-movement dependency called a chain. Assuming a biclausal structure (in order to model the so-called external and internal aspects of this kind of construction), the underlying structure is "[a] CHAIN $\langle \alpha_1, \ldots, \alpha_n \rangle$ is a sequence of nodes sharing the same θ-role such that for any i, $1 \leq i < n$, α_i c-commands and is coindexed with α_{i+1}" (Frey 2004, p. 223). Importantly, this kind of analysis aims to rescue the binding relation in terms of c-command and movement but "crucially in the absence of actual movement" (Ott 2014, p. 276).

Ott's (2014) own proposal for characterising the phenomenon takes (contrastive) left-dislocation to be a form of clausal ellipsis. Specifically, the dislocated element (*Mary* in (4)) is left over from clausal ellipsis such that, *via* deletion of the sister node containing *I think* t_i *isn't coming*, the surface form $[_{CP_1}[Mary]_i$ [I think t_i isn't coming]$[_{CP_2}$ she$_k$ I think t_k isn't coming] is produced. The account proposed by Ott is aimed at uniting left-dislocation with a more general phenomenon of elliptical construction (such as sluicing and fragment answers).

Similarly, DS aims to unite (or at least distinguish in a principled manner) this phenomenon with both right-peripheral dislocation and other constructions (such as topicalisation and relative clauses). The DS analysis is different from standard or generative accounts for sentences such as (4) and (5). It operates by means of under-specification of a tree relation and adjunction (which allows for unfixed notes to play a crucial role). So the structure in DS is one in which the dislocated element (again, *Mary*) occupies an unfixed position in the tree such that only after all the words are parsed the node is fixed and the formula value of the whole-sentence ($Ty(t)$ for truth-value) can be resolved. Consider the DS tree for a simple case (I will ignore features of the representation which do not concern my present point).

6. Mary, John dislikes. (Cann et al. 2003, p. 8)



Now, although type specifications and the like are used in the tree construction, importantly so too are structural or dominance relations (↑ and ↓ respectively). Specifically, '↑$_*$' encodes the inverse of the dominance relation or the reflexive transitive closure of the mother relation. In order to account for cases like (4) and (5), we need more machinery. Technically such cases require the LINK relation to be introduced. Marten (2005) describes the LINK relation as "not related to the matrix tree by a function-argument relation" (i.e. it is not a mother or a daughter node), it is part of the tree and imposes a requirement on the main tree that there be a copy of its formula value included" (534). In other words, LINK relates nodes in different trees structures. Then, similarly to hanging topic constructions, the pronouns or anaphors would be co-referential with the formulas of the main or host trees such that in cases such as

(6) the "left-peripheral item annotates an unfixed node within a single structure" and in (4) and (5) it "is taken to annotate a distinct structure within a pair of linked trees" (Cann et al. 2003, p. 18). The conclusion that is drawn is then:

> Notice how this modelling of natural language structure through dynamic concepts of growth replaces the static configurational approach, so that concepts such as c-command defined over a fixed structure are in general replaced by the dynamic concept of order of processing and tree development (Cann et al. 2003, p. 8).

However, it is not clear, structurally speaking, how different the various proposals really are. In the movement proposals, we saw a notion of quasi-movement, or representations that mimic actual movement, in accordance with CHAIN. In Ott's ellipsis proposal, we saw movement, deletion and biclausal structure. In DS, we have tree location underspecification which is similar to the quasi-movement of Frey (2004) and the Adjunction and LINK operations which connect different structures at the nodes, again similar to Ott's posit of two CPs with traces connecting various elements. Now of course, in terms of theory, Cann et al. (2003) are completely accurate in stating the differences in approach. In generative grammar, the various representations are not meant to be interpreted dynamically as involving processes in which one representation changes into another in real time. As Pullum (2013) cautions, even if we do adopt a mentalistic interpretation of grammar constructions, two structural descriptions (or trees), pre-movement and after-movement, are meant to be represented simultaneously not sequentially as in DS. But from a scientific modelling perspective, under a structural realist interpretation, there is continuity between the model-structures and the strategies used in these cases to model the particular linguistic phenomenon.[29]

9 Conclusion

It might be useful at this juncture to consider why this research (and the like) should be of particular importance or interest within and outwith the field of linguistics. Linguistics is in a relative scientific adolescence, often lacking a clear unified methodology, theoretical persuasion or direction. The dominance of the generative programme is under increased scrutiny and there is a plenitude of frameworks waiting in the wings to take its place. On the one extreme, divergences are often exaggerated and these frameworks are considered to be incommensurable (in the Kuhnian sense). On the other extreme, genuine differences are overlooked and considered to be mere 'notational variants' of one another (in the Chomskyan sense). The present work hopes to find a middle ground in the identification of commonalities in terms of scientific modelling practices, while respecting genuine theoretical advancements and divergences.

I have argued that the generative tradition more broadly encompasses two related varieties of modelling, namely minimal determination and isolation. These modelling

[29] Of course, much more needs to be said about the specifics of the structural realist proposal at hand. Is it "content" or "vehicle" structural realism?, What exactly are structures?, etc. Unfortunately, such a task is well beyond the present purview.

strategies fall under the auspices of a modelling practice commonly found in the sciences, namely minimalist idealisation as described by (Weisberg 2007, 2013). Under this paradigm, linguists aim to identify a core (minimal) basis which gives rise to a property or phenomenon of interest while ignoring other (even potentially relevant) features of the target system. In this sense, the strategy involves a distortion or idealisation of the target system in order to capture the least set of elements responsible for a given property. Following a line set by Blutner (2011) and Tomalin (2010), I extended this analysis beyond the standard accounts within generative grammar such as Government and Binding and the Minimalist program, to include Jackendoff's parallel architecture and optimality theory of Prince and Smolenksy. Lastly, I attempted to unite the modelling practices of the generative tradition with a competing approach which lacks the similar theoretical underpinnings of the parallel architecture and OT, namely the dynamic syntax of Kempson et al. (2001). I argued that although the theoretical claims of this latter framework are genuinely distinct from those of the specific generative programmes, they approach the target system of natural language in similar ways *via* minimalist modelling strategies. For the sake of contrast, I presented an overview of linguistic frameworks which do not share this modelling approach.

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