

communicative situations, etc. A more plausible reconstruction would be to say that connoted meanings do not contribute to the act of reference when we are dealing with materials appearing in the context of referring expressions, and, more generally, that they are not part of the truth conditions of the proposition directly associated with the meaning of the sentence in which they appear, or in other words that they belong to nonpropositional meaning. This reconstruction highlights the fact that all phenomena habitually associated with connotation exhibit the basic properties shared by all nonpropositional semantic components (e.g., they are not part of the asserted content and cannot be negated). It is clear, at the same time, that this notion of nonreferentiality is too generic to single out connotation phenomena and to distinguish them from a variety of nonpropositional meaning phenomena including illocutionary meanings, nonpropositional epistemic and evaluative attitudes, presuppositions, information structure, conversational and conventional implicatures, etc.

The relationship between the phenomena ranged under the semiotic-stylistic use of connotation and the different theoretical categories that have been developed for the study of nonpropositional meaning in semantics and pragmatics remains a largely unexplored area.

See also: Barthes, Roland: Theory of the Sign; Connotation; Descriptions, Definite and Indefinite: Philosophical Aspects; Extensionality and Intensionality; Greimas, Algirdas J.: Theory of the Sign; Hjelmslev, Louis Trolle: Theory of the Sign; Meaning, Sense, and Reference; Sense and Reference: Philosophical Aspects; Taboo, Euphemism, and Political Correctness.

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Dependency Grammar

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Introduction

Dependency grammar presents a particular perspective on how to describe the structure of natural

language expressions. This perspective is based on the notion of a dependency structure, in which we connect heads immediately with the dependents that modify them, along named relations.

Theories of dependency grammar may differ in their specific interpretation of these notions. Typically, a head defines what dependents it can take and whether a dependent is optional or not. If we describe

the level of surface form, then a head may also determine the inflectional form of a dependent, concord, and the grammatical category of the overall construction (cf. Hudson, 1984; Zwicky, 1985); at the level of semantics, the head identifies the meaningful object to which the meaning of a dependent contributes.

Theories may impose different constraints on dependency structures as such. Dependency structures are generally considered rooted structures, and all heads and dependents are connected. One point on which theories differ is whether these structures are to be trees (i.e., each dependent has a unique head; Mel'čuk, 1988; Sgall *et al.*, 1986) or can be graphs (Hudson, 1984). Another point concerns how we understand domain of a head as a linearization domain. The asymmetry between heads and dependents characterizes the vertical structural organization of an expression since heads govern dependents. A dependency structure does not *a priori* impose any linearization constraints, as these concern horizontal organization.

One immediate advantage of dependency structures is that it is easier to capture nonprojectivity found in languages with a freer word order since the linearization domains of heads are by definition not constrained, unlike constituent structure, which focuses on the horizontal organization of a linguistic expression and was traditionally based on projective domains. Dependency is not so much an alternative type of representation to constituency though, but a complementary perspective. If we combine dependency with linearization constraints, then we are incorporating a notion of constituency, albeit a flexible one, and it is this combination that has proven to be crucial in the typology of word order (Greenberg, Hawkins).

Another advantage of dependency structures is that they provide a natural way to capture the meaning that the expression realizes. Because the meaning of the expression is based on the meaning of the heads that are involved, the notion of the valency of a head is central to this. The valency of a head describes the set of dependents it can take (i.e., a type of argument structure); although often contributed to Tesnière, this notion was introduced by Peirce in the late 1890s in his proposal for analyzing natural language using relational algebra (Peirce, 1898) and appeared in writings of Bühler (1934) and of De Groot (1949). In a valency frame, we minimally state for each dependent whether it is obligatory or optional and what *role* it performs (e.g., actor or patient) (cf. also thematic structure). Valency can form the basis for verb classifications (Panevová, 1975).

The roles we use in valency frames are more than mere labels. We can define for a role its interpretative import, which determines how the dependent

contributes to the overall meaning captured by the head (Kruijff, 2001), as part of which it may introduce presuppositions that need to be satisfied in the larger discourse context. This follows the holistic perspective on interpretation Jakobson proposed based on Peirce's triadic sign, against De Saussure's binary sign structure. Interpretative import can also help explain why particular roles may bring about aspectual change (Kruijff, 2001).

Dependency grammar epitomizes a view on the structure of language that has a long history. Particularly its more recent developments are closely intertwined with the developments in modern formal grammar. Next, the basic concepts of dependency grammar are placed in this historical context to explain the concepts in more detail and to relate them to the larger context of formal grammar.

Early History of Dependency Grammar

The first formal grammar we know of, namely Panini's Ashtadhyayi (AD) grammar of Sanskrit dated ca. 350–250 B.C., includes traces of dependency. Panini's grammar was based on a long tradition of linguistic thought in India, rooted in the work of the Vedas about 5000 years ago. The AD grammar distinguishes two levels of linguistic description mediating between the surface form of an expression and its meaning. The *vibhakti* level describes the morphotactic structure of the expression, whereas the *karaka* level relates verbs and their dependents through six types of karaka relations: *karta* (agent), *karma* (patient), *karan* (instrument), *sampradan* (recipient), *apaadaan* (point of departure; cause), and *adhikaran* (location).

In the Arabic linguistic tradition (ALT), we find what is arguably the first systemic treatment of syntax based on concepts that now form the core of dependency grammar (Bohas *et al.*, 1990; Owens, 1988). Around the 8th century A.D., Arabic changed from being mainly an oral language to a language adapted for written use, in part due to a reform that made Arabic the sole administrative language of the Islam empire.

The discussions related to the Qur'an, and the collection and criticism of ancient poetry, formed the contexts in which the approach and problems of grammatical thought arose. The earliest comprehensive and systemic description of the Arabic language is the Kitab of Sibawayhi (ca. 798 A.D.), which covers phonetics, phonology, morphology, syntax, and semantics.

Sibawayhi's Kitab did not provide a theoretical model, though. Whenever the discussion concerned syntax, Sibawayhi would construct a class of related

utterances and then show by paraphrase how the individual utterances differ (Bohas *et al.*, 1990). Sibawayhi thus strongly relied on the reader's intuition to understand what to do with the data. Naturally, this left a lot of room for further interpretation. It was only in the early 10th century A.D. that a comprehensive and systematic model for grammatical theory was developed. The first explicit statement we know of this model is the *Kitab al-Usul* of Ibn al-Sarrag (d. 928).

The *Kitab al-Usul* codified the findings of Arabic grammar, as written earlier in Sibawayhi's *Kitab*. Al-Sarrag organized his system of syntax (*nahw*) around the Arabic conceptions of a head (*amil*) and its dependents (*ma'mul fihi*). Each grammatical construction had a meaning, and each part of the structure contributed its part to this meaning (Owens, 1988). Thus, we see that, for example, nominal dependents can have different roles, such as *fa'il* ('actor, subject'), *mafa'il* ('object'), as well as *mubtada* ('topic') or *khabar* ('comment'). The fact that roles are meaningful is also reflected by selectional restrictions between related items: heads only take particular types of dependents either if the head implies the existence of such a dependent or if the dependent and the head share certain features. In this context, Al-Sarrag discussed, for example, why some verbs can take locative complements – namely, if they imply a general location for the action to occur in.

In Medieval Europe, grammarians were familiar with the ALT due to the close interaction with the Islamic world through Moorish culture in southern Europe and the use of Hebrew by Jews all over Europe. Arabic grammar interested them because Arabic was a language different from Latin and had resulted in a different kind of grammar, thus raising the question whether there is a universal grammar. The major impact on linguistic thought came through the translated work of the ancient logicians and grammarians, which (re-)introduced the notions of syntactic and semantic dependency.

In Antiquity, logicians such as Aristotle focused on how propositions could be analyzed into their constituent parts. They distinguished two main word classes, namely nouns and verbs (credited to Plato), which when put together constitute a minimal proposition: the noun provides the subject and the verb provides the predicate for a proposition. The notion of dependency we find here is of a semantic nature. Without a verb, we do not have a proposition, as Aristotle observes in *On Interpretation*.

At the same time, the Antique grammarians concentrated on the interpretation of literary texts. Besides nouns and verbs, the grammarians also distinguished participles, articles, pronouns, prepositions, adverbs,

and conjunctions as word classes. Although the grammarians did not adopt a logic-based analysis, the grammarians did inherit nouns and verbs as word classes from the logicians, and as such the two systems were not unrelated. For example, the grammarians conceived of the adverb as "a part of speech that complements or diminishes the meaning of the verb that it accompanies" (Percival, 1990, p. 31). This illustrates two implications (Percival, 1990). First, there is the notion of semantic specification: the function of some words is to clarify or add to the meanings of other words (i.e., semantic dependency). Second, there are asymmetrical relations: an adverb needs a verb to modify, but a verb does not necessarily need an adverb to be modified by (i.e., a syntactic dependency). These two ideas were elaborated in the work of Apollonius (2nd century A.D.). Later, the Latin scholar Priscian (ca. 500 A.D.) based his Latin grammar on Apollonius's ideas.

These notions came into European Medieval grammar through Boethius's (ca. 480–524/6 A.D.) interpretation of Aristotle's work. In his commentary on Aristotle's *On Interpretation*, we for the first time find a special term to refer to the supportive function of minor word classes, namely '*determinationes*' ('specifiers') (Percival, 1990). Boethius elaborates this notion in his *De Divisione* by saying that words in isolation are vague and need to be specified further. Determination thus cuts across word classes, adding an idea of semantic role to the major word classes.

The writings of Boethius were part of the *logica vetus* on which Medieval education was based. Under the influence of the newly accessible works of Aristotle and other Greek philosophers, this led to a revival of the view of language as developed by the Antique logicians. The scholastics wanted to explain the sciences on the basis of a set of propositions whose truth could be inferred conclusively by deduction from first principles and that naturally included grammar. Grammarians quickly adopted Boethius's *determinatio* and complemented it with the more syntax-oriented notion of *regimen* ('government'): a verb governs all the major nominal expressions in a sentence, determining, e.g., nominal inflection (which is similar to the notion of head in the ALT). Other government relations were *exigentia* ('requirement') between adverbs and verbs and *deservire* (or *servire*) between prepositions and nouns (Percival, 1990).

By the end of the 12th century, grammarians used both *regimen* and *determinatio*, and in the 13th century, Latin grammarians introduced the term *dependentia*. This term was closely related to *determinatio*, and it expressed the affinity between syntactic and semantic dependency: "If A governs B, then B determines A, and hence A is dependent on B, with

‘B terminating the dependency’” (Percival, 1990, p. 35). These notions were consequently used by speculative and modistic grammarians in the following centuries, particularly Thomas of Erfurt and Martin of Dacia (Covington, 1984).

In the 17th century, the logicians of Port Royal revived the ideas of speculative grammar. In 1660, they published their *Grammaire générale et raisonnée* and the *Logique*, with which they wanted to demonstrate how the structure of language is a product of reason, and that the different languages are varieties of a more general logical and rational system. At the time, grammarians added several important concepts to the notion of dependency. The Port Royal logicians introduced the notion of a dependent clause. Contributed to the French grammarian Claude Buffier (early 18th century) are the notions of modifiers and modification, whereas Girard introduced the notion of complement in 1747 (Percival, 1990).

Modern History

The modern advancements in dependency grammar are best seen within the larger context of the developments in formal grammar. At the end of the 19th century, Wundt (1932–1920) introduced an analytical perspective on natural language syntax in which we start with a sentence and attempt to decompose it into its parts, unlike the synthetic view of the Antiques and the Medieval grammarians who investigated how sentences result from combining words. The analytical perspective is evident in Bloomfield’s immediate constituency hypothesis but finds its clearest expression in the formal frameworks that have been developed since the 1950s. Crucial to these developments was the groundbreaking work during the 1930s and 1940s on mathematical logic and on the theory of computers and computation. For example, Post’s work on rewriting systems provided the formal basis for what later became phrase structure grammars (PSGs).

This was the background against which Chomsky could formulate his ideas that had a profound impact on the enterprise of modern theories of syntax: the mathematical results establishing formal language theory and the scale of types of grammar (the *Chomsky hierarchy*), the critical review of B. F. Skinner’s (1957) *Verbal behavior* that spelled the end of descriptive behaviorism, and his book *Syntactic structures* (Chomsky, 1957). *Syntactic structures* not only presents a formalization of the immediate constituency hypothesis in the form of a PSG for English but also advances an important methodological point. The preface emphasizes the heuristic role of formalization in clarifying linguistic analyses. We can define the

grammar of a language as a finite set of rules, which is a mathematical theory of the syntactic structure of that language. As such, we can compute its consequences and verify these against empirical evidence.

Chomsky proposed to view natural language grammar as a generative grammar. A generative grammar consists of a context-free (CF) component that generates ‘kernel sentences’ and transformations that derive complex representations from the kernel sentences, a division originating with Harris. Chomsky considered two variants of this system. In variant A, we generate a (finite) set of elementary sentences and then use transformations to obtain the class of representations of all sentences for a language. In variant B, we directly generate a (finite) set of representations for all sentences of a language and then use transformations to arrive at surface forms.

Variant B formed the basis for stratificational grammar, developed in Hays (1964) and Lamb (1966). In 1965, Chomsky also adopted variant B, combining the ideas of kernel and transformations into the notion of transduction. Together with the dependency theory of Hays and Tesnière, this gave rise to the first modern formal frameworks for dependency grammar.

The modern notion of dependency grammar is usually attributed to Tesnière, published posthumously as Tesnière (1959) (dating back to 1939). Tesnière aimed at a notion of grammar that would be useful in teaching foreign languages. His theory has two parts: the dependency theory and the translation theory. The dependency theory describes how to analyze a sentence in terms of *l’ordre structurel* and *l’ordre linéaire* – what we nowadays would understand as immediate dominance (or dependency) and linear precedence, respectively. To obtain the dependency structure of a sentence, Tesnière suggested to first divide the sentence into primitive elements called nuclei. A nucleus can consist of one or more words (possibly but not necessarily forming a contiguous sequence), although a nucleus can also be just a part of a word. Next, a syntactic structure is built by directly relating nuclei through connexions. A connexion is a directed and named relation from a regent (head) to a dependent. Each dependent has exactly one regent, and there is a single root nucleus, as a result of which Tesnière’s dependency structures are trees – but unordered trees because they do not model linearization. Furthermore, where it concerned taxis (e.g., coordination), Tesnière proposed a separate dimension.

Tesnière’s dependency trees, being unordered, left open the possibility for combining dependency grammar with a notion of (immediate) constituency [see Hockett’s *Course in Modern Linguistics* (1958) and

Nida's *A Synopsis of English Syntax* (1966)]. Because of the close affinity between dependency grammar and categorial grammar, various authors have proposed to use categorial grammar to model the linearization aspect (Kruijff, 2001).

Employing Tesnière's ideas, various formalizations based on stratificational grammar were proposed. In the early 1960s, Sgall proposed a transductive approach, derived from Chomsky's variant B, which led to the first formulation of functional generative description (FGD) (Sgall *et al.*, 1969). FGD presents a purely dependency based formalism (Petkevič, 1987; Sgall *et al.*, 1986), in which a surface form is generated from a tectogrammatical representation through a sequence of n transduction steps over successive representational strata. Plátek and Sgall (1978) established that although the pushdown automata used as transducers do extend the generative strength of the approach beyond context freeness, the result does not reach context sensitivity.

In FGD, we see a symbiosis of Praguian functionalism (Mathesius, Jakobson) and structuralism. Tesnière suggested a purely structuralist approach to relating surface form and meaning, essentially considering a one-to-one mapping. FGD instead is based on the functionalist idea that every form is motivated by the underlying function it expresses, but it combines this with the idea that we should only distinguish functions if they are realized differently (Panevová, 1974). This sets FGD apart from purely functionalist approaches such as that of Fillmore (1968), according to a crucial role to the form/function relation while at the same time FGD is functional in that meaning provides the basis for surface form.

Other stratificational approaches to dependency grammar are meaning-text theory (MTT) (Gladkij and Mel'čuk, 1975; Mel'čuk, 1988) in the Russian School and *Abhängigkeitsgrammatik* (Kunze, 1975) in the German School. The German School focused especially on the integration of valency theory into the general idea of dependency syntax (e.g., work by Helbig, Heringer, Kunze, and Engel; Helbig presented a substantial dependency grammar of German).

The MTT, first put forward in Moscow by Zholkovskij and Mel'čuk in 1965, is similar to FGD in that it consists of mapping, in successive stages, from the meaning of an utterance to its form or 'text.' MTT distinguishes, from deep to surface, levels for representing semantics, syntax, morphology, and phonology. At each of these levels, we may distinguish different dimensions of a representation; for example, in semantics we have communicative functions besides the semantic structure capturing propositional content. MTT formed the basis for one of the first substantial English grammars, which Mel'čuk

and Pertsov developed in Russia during the early 1970s. The most fundamental difference between MTT and FGD is in their understanding of dependency. MTT assumes that each construction is headed, including coordination (Mel'čuk, 1988); FGD instead follows Tesnière's proposal to consider taxis a separate structural dimension.

Parallel to the development of MTT and FGD was Hudson's work on dependency grammar, inspired by Halliday's systemic (functional) grammar. An early proposal for daughter-dependency grammar (1976) adopted the goal of generative grammar (i.e., modeling the sentences of a language) but took a nontransformational approach: a sentence has only one representation (stratum), and there are no transformations – unlike MTT or FGD. This view prevails in Hudson's later work on word grammar (WG) (Hudson, 1984). WG is a dependency grammar in that its structures are built from immediate dependencies between words, with the dependencies indicating what grammatical relation the dependent fulfills. The resulting dependency structures are not trees but graphs ('networks'). WG presents language as a network of knowledge, using default inheritance in linking concepts about the meanings of words without strictly distinguishing linguistic knowledge from, for example, world knowledge. WG focuses first on a rich representation of the meaning of an utterance and less on aspects of its linearization.

In the 1960s and 1970s, developments in dependency grammar thus investigated both syntactic and semantic notions of dependency, the latter placed within the more general question on how semantics and syntax relate (cf. the issue of the autonomy of syntax). Semantic dependency was mostly investigated from the viewpoint of valency, exploring Tesnière's notions of *actants* ('arguments') and *circumstants* ('adjuncts'); see Panevová (1974, 1975) (FGD), Fillmore (1968), as well as work by Starosta on lexica and the German School.

Formal language theory made it possible to ask for the generative power of a grammar, and for dependency grammar various authors had established such results. Hays (1964), Gaifman (1965), and Robinson (1970) all showed that a class of dependency grammars are weakly equivalent to context-free phrase structure grammars. However, Gross (1964) claimed that "the dependency *languages* are exactly the context-free languages" (p. 49). Similar mistaken claims were made frequently in the literature; unfortunately so, unfortunately because early on CFGs were shown to be inadequate to model natural language. This might have been the reason why, at the time, people lost interest in dependency grammar, at least in its syntactic exponents.

Traditional PSG (following Bloomfield) was also CF, but Chomsky (1957) added transformations on top of such a grammar to obtain greater generative power. However, this did not necessarily solve the problem. People criticized transformations for not having corresponding linguistic concepts, and Peters and Ritchie showed that formally, transformations are problematic in that generative strength cannot easily be restricted. However, it took empirical evidence to show that a dependency-based view on syntax does have merit, and it required further developments in formal frameworks to create stronger dependency grammars.

Empirical evidence came from the study of non-configurational languages, which started in the 1970s. These studies showed that relations rather than phrases are typologically significant, and that a relational view on structure is better capable to model varying degrees of word order freedom. This led to a reconsideration of asymmetric relations, giving rise in the early 1980s to new nontransformational grammar frameworks like relational grammar and lexical-functional grammar, which showed that a relational perspective can lead to better cross-linguistic generalizations.

Parallel lines of development in computer science, starting in the late 1970s and continuing through the 1980s, yielded new formal systems that went beyond CFGs. One line led to systems that make more derivational power available in a restricted, or at least controlled, fashion. This dates back at least to the introduction of tree-adjoining grammar (TAG) in 1975. TAG presents a nontransformational formalization of Chomsky (1957) using mildly context-sensitive grammars. In the 1980s, combinatory categorial grammar introduced an algebraic system based on combinatory logic that is also mildly context sensitive, whereas linear logic provides the proof-theoretic basis for a family of categorial grammars that can increase to context sensitivity in a controlled fashion. Another line has led to the constraint-based or model-theoretic perspective on formal grammar. This finds its roots in feature logics, developed in the 1980s by Kasper, Rounds, Johnson, and Moshier, and in constraint programming. Feature logics were rapidly embraced in formal grammar (e.g., HPSG), whereas constraint programming provided a means to implement parsers for model-theoretic frameworks.

The importance of these developments for dependency grammar is twofold. First, many of the new (nontransformational) grammar formalisms include a dependency-based perspective, notably the inclusion of the head/dependent asymmetry in HPSG and several types of categorial grammar (Kruijff, 2001).

Second, they have made it possible to present novel formalizations of dependency grammar and to renew the investigation into the complexity of dependency-based syntax (Neuhaus and Bröker).

TAG has provided the basis to model syntactic dependency (e.g., d-tree grammar) (Rambow *et al.*, 2001) and to give a formalization of MTT (Candito and Kahane, 1998). Similarly, Kruijff (2001) provides a nontransformational formalization of FGD based on categorial grammar, modeling dependency-based semantics using description logics in which also the interpretative import of dependency relations can be explicitly modeled.

Within the model-theoretic view on syntax, several novel formalizations of dependency grammar have been proposed. Dependency unification grammar (Hellwig, 2003) and Maxwell's (1995) unification dependency grammar are based on the idea of using unification to combine grammatical structures, as in HPSG. Duchier and Debusmann (2001) showed how powerful constraint programming techniques can be used to provide a dependency grammar formalism. They proposed a formalism in which several representations can co-constrain one another (e.g., immediate dominance next to linear precedence), whereby complex phenomena emerge from the interaction between these representations. To handle word order of any degree of freedom, they used topological fields; for a similar idea, see Gerdes and Kahane (2001) or Bröker (1997) (who uses modal logic). Debusmann *et al.* (2004) showed how any number of levels of representations can be included, for example, to model the syntax/semantics interface.

Examples of more processing-oriented approaches are Tapanainen and Järvinen's functional dependency grammar parser; the link grammar parser by Temperley, Sleator, and Lafferty; and various types of statistical (treebank-based) parsers by Collins, Giguët and Vergne, and Eisner.

See also: Categorial Grammars: Deductive Approaches; Combinatory Categorial Grammar; Computational Linguistics: History; Construction Grammar; Dependency Phonology; Functionalist Theories of Language; Head-Driven Phrase Structure Grammar; Lexical Functional Grammar; Lexicase; Prague School; Valency Grammar.

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