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Competence/Performance Distinction

See INTRODUCTION: LINGUISTICS AND LANGUAGE; LINGUISTICS, PHILOSOPHICAL ISSUES; PARAMETER-SETTING APPROACHES TO ACQUISITION, CREOLIZATION, AND DIACHRONY

Competition

See COOPERATION AND COMPETITION; GAME THEORY

Competitive Learning

See UNSUPERVISED LEARNING

Compliant Control

See CONTROL THEORY; MANIPULATION AND GRASPING

Compositionality

Compositionality, a guiding principle in research on the SYNTAX-SEMANTICS INTERFACE of natural languages, is typically stated as follows: "The meaning of a complex expression is a function of the meanings of its immediate syntactic parts and the way in which they are combined." It says, for example, that the meaning of the sentence

$$_{S}[_{NP}\ \textit{Zuzana}\ [_{VP}\ [_{V}\ \textit{owns}\ ]\ [_{NP}\ \textit{a schnauzer}\ ]]],$$

where the commonly assumed syntactic structure is indicated by brackets, can be derived from the meanings of the NP *Zuzana* and the VP *owns a schnauzer,* and the fact that this NP and VP are combined to form a sentence. In turn, the meaning of *owns a schnauzer* can be derived from the meanings of *owns* and *a schnauzer* and the fact that they form a VP; hence, the principle of compositionality applies recursively. The principle is implicit in the work of Gottlob FREGE (1848–1920), and was explicitly assumed by Katz and Fodor (1963) and in the work of Richard Montague and his followers (cf. Dowty, Wall, and Peters 1981).

In some form, compositionality is a virtually necessary principle, given the fact that natural languages can express an infinity of meanings and can be learned by humans with finite resources. Essentially, humans have to learn the meanings of basic expressions, the words in the LEXICON (in the magnitude of 10^5), and the meaning effects of syntactic combinations (in the magnitude of 10^2; see SYNTAX). With that they are ready to understand an infinite number of syntactically well-formed expressions. Thus, compositionality is necessary if we see the language faculty, with Wilhelm von Humboldt, as making infinite use of finite means. But compositionality also embodies the claim that semantic interpretation is local, or modular. In order to find out what a (possibly complex) expression *A* means, we just have to look at *A*, and not at the context in which *A* occurs. In its strict version, this claim is clearly wrong, and defenders of compositionality have to account for the context sensitivity of intepretation in one way or other.

There are certain exceptions to compositionality in the form stated above. Idioms and compounds are syntactically complex but come with a meaning that cannot be derived from their parts, like *kick the bucket* or *blackbird.* They have to be learned just like basic words. But compositionality does allow for cases in which the resulting meaning is due to a syntactic construction, as in the comparative construction *The higher they rise, the deeper they fall.* Also, it allows for constructionally ambiguous expressions like *French teacher*: *French* can be combined with *teacher* as a modifier ("teacher from France"), or as an argument ("teacher of French"). Even though the constituents are arguably the same, the syntactic rules by which they are combined differ, a difference that incidentally shows up in stress (see STRESS, LINGUISTIC).

A hidden assumption in the formulation of the principle of compositionality is that the ways in which meanings are combined are, in some difficult-to-define sense, "natural." Even an idiom like *red herring* would be compositional if we allowed for unnatural interpretation rules like "The meaning of a complex noun consisting of an adjective and a noun is the set of objects that fall both under the meaning of the adjective and the meaning of the noun, except if the adjective is *red* and the noun is *herring,* in which case it may also denote something that distracts from the real issue." But often we need quite similar rules for apparently compositional expressions. For example, *red hair* seems to be compositional, but if we just work with the usual meaning of red (say, "of the color of blood"), then it would mean something like "hair of the color of blood." *Red hair* can mean that (think of a punk's hair dyed red), but typically is understood differently. Some researchers have questioned compositionality because of such context-dependent interpretations (cf. Langacker 1987). But a certain amount of context sensitivity can be built into the meaning of lexical items. For example, the context-sensitive interpretation of *red* can be given as: "When combined with a noun meaning N, it singles out those objects in N that appear closest to the color of blood for the human eye." This would identify ordinary red hair when combined with *hair.* Of course, prototypical red hair is not prototypically red; see Kamp and Partee (1995) for a discussion of compositionality and prototype theory.

Another type of context-sensitive expression that constitutes a potential problem for compositionality is pronouns. A sentence like *She owns a schnauzer* may mean different things in different contexts, depending on the antecedent of *she.* The common solution is to bring context into the formulation of the principle, usually by assuming that "meanings" are devices that change contexts by adding new information (as in models of DYNAMIC SEMANTICS, cf. Heim 1982; Groenendijk and Stokhof 1991). In general, compositionality has led to more refined ways of understanding MEANING (cf. e.g., FOCUS).

In the form stated above, compositionality imposes a homomorphism between syntactic structure and semantic interpretation: syntactic structure and semantic interpretation go hand in hand. This has led to a sophisticated analysis of the meaning of simple expressions. For example, while logic textbooks will give as a translation of *John and Mary came* a formula like $C(j) \wedge C(m)$, it is obvious that the structures of these expressions are quite different—the syntactic constituent *John and Mary* does not correspond to any constituent in the formula. But we can analyze *John and Mary* as a QUANTIFIER, $\lambda X[X(j) \wedge X(m)]$, that is applied to *came*, C, and thus gain a structure that is similar to the English sentence. On the other hand, compositionality may impose certain restrictions on syntactic structure. For example, it favors the analysis of relative clauses as noun modifiers, [*every* [*girl who came*]], over the analysis as NP modifiers [[*every girl*] [*who came*]], as only the first allows for a straightforward compositional interpretation (cf. von Stechow 1980).

Compositionality arguments became important in deciding between theories of interpretation. In general, semantic theories that work with a representation language that allows for unconstrained symbolic manipulation (such as Discourse Representation Theory—Kamp 1981; Dynamic Semantics, or Conceptual Semantics—Jackendoff 1990) give up the ideal of compositional interpretation. But typically, compositional reformulations of such analyses are possible.

See also DISCOURSE; SEMANTICS

—Manfred Krifka

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Computation

No idea in the history of studying mind has fueled such enthusiasm—or such criticism—as the idea that the mind is a computer. This idea, known as "cognitivism" (Haugeland 1981/1998) or the COMPUTATIONAL THEORY OF MIND, claims not merely that our minds, like the weather, can be modeled on a computer, but more strongly that, at an appropriate level of abstraction, we *are* computers.

Whether cognitivism is true—even what it means—depends on what computation is. One strategy for answering that question is to defer to practice: to take as computational whatever society *calls* computational. Cognitivism's central tenet, in such a view, would be the thesis that people share with computers whatever constitutive or essential property binds computers into a coherent class. From such a vantage point, a theory of computation would be *empirical,* subject to experimental evidence. That is, a theory of computation would succeed or fail to the extent that it was able to account for the machines that made Silicon Valley famous: the devices we design, build, sell, use, and maintain.

Within cognitive science, however, cognitivism is usually understood in a more specific, theory laden, way: as building in one or more substantive claims about the nature of computing. Of these, the most influential (especially in cognitive science and artificial intelligence) has been the claim that computers are *formal symbol manipulators* (i.e., actively embodied FORMAL SYSTEMS). In this three-part characterization, the term "symbol" is taken to refer to any causally efficacious internal token of a concept, name, word, idea, representation, image, data structure, or other ingredient that represents or carries information about something else (*see* INTENTIONALITY). The predicate "formal" is understood in two simultaneous ways: *positively,* as something like *shape, form,* or *syntax,* and *negatively,* as *independent of semantic properties,* such as reference or truth. *Manipulation* refers to the fact that computation is an active, embodied process—something that takes place in time. Together, they characterize computation as involving the active manipulation of semantic or intentional ingredients in a way that depends only on their formal properties. Given two data structures,