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## Preface

The two volumes published by Ontos – *The Compositionality of Meaning and Content: Foundational Issues* and *The Compositionality of Meaning and Content: Applications to Linguistics, Psychology and Neuroscience* – bring together scientists from the disciplines that presently constitute cognitive science – psychology, neuropsychology, philosophy, linguistics, logic, and computational modelling. The purpose was to cast some light on a shared topic of interest, *compositionality*. To our knowledge, this is the first time that researchers from almost the whole spectrum of cognitive science unite their efforts to understand this important phenomenon.

The contributions to these volumes originated in presentations to two conferences organized by the editors of these volumes. The first conference, *CoCoCo – Compositionality, Concepts, & Cognition*, was organized in March 2004 at the Heinrich-Heine University of Düsseldorf, Germany. The second, *NAC 2004 – New Aspects of Compositionality*, was organized in June 2004 at the Ecole Normale Supérieure, Paris, France. A dynamic group of cognitive scientists, including philosophers, psychologists, linguists, computer scientists and neuroscientists, took part in these two lively conferences and shared their insights concerning compositionality with the other conference participants. Both conferences were very well-attended and gave rise to discussions, exchanges, and controversies that were, we are convinced, fruitful for all participants. We doubt anybody left these conferences without having improved her grasp on the issues connected to compositionality.

These two conferences resulted from a frustration shared by the editors of these two volumes a couple of years ago. Cognitive science is essentially an interdisciplinary enterprise. And compositionality is a salient issue that is common to most disciplines in cognitive science, as is amply illustrated by these two volumes. In computational modelling and in artificial intelligence, compositionality had been an important issue, at least, since Fodor and Pylyshyn's (1988) well-known criticism of connectionist models. This article sparked an intensive research on whether and how non classical models of cognition, primarily connectionist models, could accommodate compositionality (e.g., Smolensky, 1988, 1991; Van Gelder, 1990; Levy & Gayler, 2004; Werning & Maye, 2004, Werning, 2005).

Among linguists, the methodological status of compositionality in semantics has been intensively scrutinized (e.g., Partee, 1984; Janssen, 1986, 1997). In the

philosophy of psychology, Fodor has based his case against philosophical and psychological theories of concepts on compositionality (Fodor & Lepore, 1992, 1996; Fodor, 1998a). In philosophy of science since Quine (1951), Carnap (1956) and Kuhn (1962), it has often been argued that the meaning of theoretical concepts is dependent on the background theory (Schurz, 2005). Kuhn and many other philosophers of science have therefrom inferred a holistic theory-dependence of meaning to the effect that the meaning of theoretical concepts seems to be non-compositional (Fodor, 1987).

There have also been some recent major advances in issues concerned with compositionality in several disciplines. The formal treatment of compositionality has been considerably advanced by the work of Wilfrid Hodges (1998, 2001; see also Zadrozny, 1994; Westerståhl, 1998, Werning, 2004). In psychology, new models of concept composition were proposed in the nineties (e.g., Wisniewski, 1996; Costello & Keane, 2000). Finally, both experimental and modelling issues connected to compositionality have been important in the vibrant field of cognitive neuroscience (Shastri & Ajjanagadde, 1993; Werning, 2003, 2005; Werning & Maye, 2004; van der Velde & de Kamps, forthcoming). In spite of all this work on issues connected to compositionality, there had been little contact across the disciplines that constitute cognitive science. To remedy this interdisciplinary deafness and to further the exchange of views across disciplines in cognitive science, we decided to gather a group of cognitive scientists actively working on compositionality.

Several contributions to the resulting conferences in Düsseldorf and Paris have been put together in the two volumes. We are not under the illusion that these two volumes cover all the issues that are connected to compositionality. To illustrate, there is no contribution from classical computer science, although compositionality is also a significant issue in this discipline. In linguistics, the recent debates concerning direct compositionality – the idea, roughly, that semantics works in tandem with the syntax, i.e., that each expression is directly assigned an interpretation as it is syntactically constructed (Jacobson, 1999) – are not represented here. Nonetheless, we think that the contributions gathered in these two volumes cover a substantial fraction of the issues connected to compositionality in cognitive science. We hope that cognitive scientists will find these two volumes helpful and inspiring. We wish that they will further the development of an interdisciplinary approach to issues around compositionality.

The two conferences on compositionality would not have been possible without the support of various institutions. Compositionality, Concepts, & Cognition in Düsseldorf was generously funded by the Thyssen Foundation and the Heinrich-Heine University, Düsseldorf, while *New Aspects of Compositionality* in Paris was financially supported by the RESCIF (Réseau des Sciences

Cognitives en Ile-de-France), the department of cognitive studies at the Ecole Normale Supérieure in Paris, the University of Paris-Sorbonne, and the Institut Jean-Nicod. We, the editors, would like to thank these institutions for their support.

We are also pleased to express our gratitude to those who have trusted us and who have supported our efforts. We would particularly like to thank Daniel Andler, director of the department of cognitive studies at the Ecole Normale Supérieure, who backed this project from the outset, as well as Pascal Engel (University of Paris-Sorbonne, philosophy department) and Pierre Jacob (Institut Jean-Nicod, Paris).

We would like to thank the prestigious scientific board for the two conferences in Paris and Düsseldorf, which consisted of the following distinguished scholars: Daniel Andler (department of cognitive studies, ENS, Paris), Peter Carruthers (department of philosophy, University of Maryland), James Hampton (department of psychology, City University London), Douglas Medin (department of psychology, Northwestern University), Jesse Prinz (department of philosophy, University of North Carolina, Chapel-Hill), Francois Recanati (Institut Jean-Nicod, Paris), Philippe Schlenker (department of linguistics, UCLA), and Dag Westerståhl (department of philosophy, University of Gotenborg).

We would also like to thank the referees for the two volumes: Claire Beyssade, Daniel Cohnitz, Fabrice Correia, David Danks, Jérôme Dokic, Chris Eliasmith, Manuel Garcia-Carpintero, James Hampton, Heidi Harley, Paul Horwich, Theo Janssen, Kent Johnson, Ingrid Kaufman, Marcus Kracht, Hannes Leitgeb, Pascal Ludwig, Alexander Maye, Thomas Müller, Reiner Osswald, Elisabeth Pacherie, Peter Pagin, Jérôme Pelletier, Josh Schechter, Benjamin Spector, Su Xiaoqin, and Dan Weiskopf.

Finally, in the making of the Düsseldorf conference a number of helpful hands were involved: in particular, those of Myung-Hee Theuer, Marc Breuer, Jens Fleischhauer, Hakan Beseoglu, Markus Stalf, Eckhart Arnold, Nicole Altvater, Marco Lagler, Sven Sommerfeld, and Celia Spoden. The Parisian conference would not have been possible without the help of Evelyne Delmer at the department of cognitive studies of the Ecole Normale Supérieure. To all those we cordially express our thanks.

### *Compositionality – a plurality of ideas*

It is time to say a few words about what compositionality is. In what follows, we briefly review the issues connected to compositionality in the disciplines represented in the two volumes. Before going any further, we would like to emphasize an important *caveat*. Although “compositionality” has a rather precise

definition, particularly in logic and linguistics, it is used in various ways in philosophy, psychology, neuroscience, etc. It is thus always worthwhile wondering what an author means when she uses this notion.

In spite of this *caveat*, “compositionality” is usually taken to refer to a property of some representational systems, primarily of languages – be they natural languages like French or English, artificial languages like mathematical or logical languages, or hypothetical languages like the language of thought. As a first approximation, an interpreted representational system  $R$  is compositional if and only if for every complex representation  $r$  of  $R$ , the meaning of  $r$  is determined by the structure of  $r$  and the meaning of the constituents of  $r$ . It is well-known that there are many, more or less precise variants of this principle (Hodges, 1998), but, for present purposes, this formulation will do. The principle of compositionality applies to a representational system  $R$  that contains simple representations and complex representations. Complex representations are made out of other representations – their constituents – according to rules of composition. These rules of composition – the syntax in the case of languages – determine the structure of the complex representations. Simple and complex representations of  $R$  are interpreted.  $R$  is compositional if and only if the interpretations of the simple and complex representations of  $R$  obey the principle of compositionality proposed above (or one of its variants).

### ***Logic***

In logic, there has been an intense work on the formal properties of compositional languages (for an introduction, see, particularly, the *Journal of Logic, Language and Information*, 10(1), edited by P. Pagin and D. Westerståhl in 2001). Logicians have focused primarily on the following issues. Precise formalisms have been developed to rigorously formulate the principle of compositionality (as well as its variants). In this area, the work of Wilfrid Hodges is remarkable (see, particularly, Hodges, 2001). Following Montague (1970/1974), he has developed an algebraic framework, which allows him to specify various notions of compositionality. On this basis, Hodges (2001) has shown that any syntactically specified language can be provided with a compositional semantics. This result falsifies Hintikka’s claim that Independence-Friendly Logic is non-compositional (Hodges, 1997; Sandu & Hintikka, 2001). Nonetheless, it remains that when the meaning of the primitive elements of the vocabulary of the logical language is constrained, not every syntactically characterized language has a compositional semantics.

Hodges’ results also raise the question of the putative triviality of the principle of compositionality (Zadrozny, 1994; Kazmi & Pelletier, 1998; Westerståhl, 1998). Two important areas of research are also worth pointing to, the relation

between compositionality and context and, from an historical point of view, the place of compositionality in Frege's logic and philosophy (e.g., Janssen, 2001).

In our two volumes, Tim Fernando, Ahti-Vieikko Pietarinen, Oleg Prosorov, and Gerhard Schurz focus on logical issues connected with compositionality. Interestingly, although the first three papers are committed to three different formal frameworks, they all focus on the relation between compositionality and context. Fernando's article follows and develops Hodges' and Westerståhl's approach. He shows that compositionality can be approached in two different ways, which he calls "inductive" and "co-inductive." Pietarinen and Prosorov explore new territories. Pietarinen's article centers on the relation between compositionality and Peirce's contributions to logic and semantics. Of particular interest is his discussion of how Peirce's logic integrates context-sensitivity and compositionality. Prosorov develops a new formalism to deal with compositionality. Like Fernando and Pietarinen, he discusses in detail the relation between context-sensitivity and compositionality.

Finally, Schurz critically discusses Hodges' theorem, which proves that under certain natural conditions, a compositional semantics always exists. Schurz argues that this does not imply that humans actually compute the meanings of terms along a compositional function. Rather, one should distinguish between logical and epistemic compositionality. He argues that the Ramsey/Lewis account of theories provides a semantics for theoretical terms that is compositional in the logical, but not in the epistemic sense.

### *Linguistics*

Compositionality has fuelled many debates in linguistics. The principle of compositionality was an important element of Davidson's and Montague's approaches to semantics (Davidson, 1965/2001; Montague, 1970/1974). However, its methodological status was left unclear. Since, the question of the methodological status of compositionality has been a constant bone of contention in semantics (Partee, 1984). One can wonder, for instance, whether it is an empirical or a methodological (heuristic) principle. One can also question the utility of this principle, if it is viewed as a methodological principle. This methodological debate is often articulated as an empirical debate: Are natural languages compositional? It has indeed been occasionally claimed that compositionality is more or less frequently violated in natural languages (Higginbotham, 1986; Pelletier, 1994; Fodor, 2001), sparking a debate about the correct linguistic analysis of the putative counter-examples to compositionality.

Recently, three issues connected to compositionality have attracted linguists' attention – direct compositionality, impossible words, and the evolution of compositional languages. As noticed above, the direct compositionality approach is,

roughly, the idea that every syntactic operation is interpreted (Jacobson, 1999). The impossible words debate can be put as follows (Hale & Keyser, 1993, 1999; Fodor & Lepore, 1999, 2005; Johnson, 2004). According to many linguists in lexical semantics, many monomorphemic lexical items like “boy” or “table” have a linguistic structure. For instance, to use a classical example, the linguistic structure of “kill” could be “cause to die.” There is no consensus on the correct lexical decomposition, but linguists agree that when we understand monomorphemic lexical items, we decompose them into simpler elements. Fodor and Lepore (1999) disagree. They argue that by and large, lexical items like “dog” are primitive: They do not decompose.

The impossible words argument is supposed to support the decomposition approach of lexical linguists. The idea is, roughly, that the decomposition approach explains why, as Fodor and Lepore recently put it (2005, p. 354), there is no verb in English “like *blik* such that ‘The desk *bliked* Mary’ means Mary broke the desk (i.e. why there aren’t transitive verbs whose subjects are their thematic patients).” Finally, there is a growing body of research on the evolution of compositional natural languages. In recent years, many models have been proposed to account for the appearance of compositional natural languages (e.g., Brighton, 2002; Smith, Brighton, & Kirby, 2003).

In our two volumes, several articles bear on the issues connected with compositionality in linguistics. The compositionality of natural languages is closely scrutinized by Gayral, Kaiser and Lévy. They argue that natural languages are not compositional and conclude that traditional linguistic frameworks are inadequate for explaining linguistic understanding. Taking an opposite stance, Reinaldo Elugardo critically focuses on Fodor’s (2001) argument that natural languages are non-compositional and thus that linguistic meaning is derived from original, compositional mental content. Jaume Mateu’s article engages in the controversy about impossible words in lexical semantics, siding with Hale and Keyser. Jaroslav Peregrin’s and Daniel Cohnitz’ articles focus on the status of the principle of compositionality. Peregrin rejects the idea that it is an empirical generalization concerning natural languages and proposes instead that compositionality and meaning are conceptually linked. On the contrary, Cohnitz rebuts the arguments to the effect that compositionality is a priori true. He argues for a substantial notion of compositionality.

Shelley Ching-yu Hsieh, Chinfu Lien and Sebastian Meier’s and Olav Müller-Reichau’s articles are more empirical. Hsieh et al. focus on the meaning of expressions for plants, vegetables and trees (e.g., “garlic”, “cabbage”) in Mandarin Chinese and German. Müller-Reichau focuses on the relation between semantic composition and the type/token distinction. Henry Brighton’s article focuses on the evolution of compositional natural languages. Finally, Filip Buekens is concerned with the linguistic processing of aberrant sentences.



## *Philosophy*

The topic of compositionality has given rise to various debates in philosophy. We here review two, to some extent related issues – compositionality and the nature of meaning, compositionality and the nature of concepts. The nature of meaning, first. Since compositionality is a property of interpreted representational systems, one can wonder whether (or to what extent) compositionality constrains what meaning is in general or what meaning is, for a given language or representational system. This is a very controversial area. Particularly, Fodor and Lepore (1992) have argued that compositionality is inconsistent with most views concerning what meaning is or what meaning supervenes upon (Fodor & Lepore, 1992, 2002). For instance, Fodor and Lepore argue that the meaning of a symbol cannot be identified with, nor supervene upon the use of this symbol (or its functional role if it is a mental symbol).

Others have taken diametrically opposed views. Particularly, Horwich (1997) has argued that compositionality does not constrain the nature of meaning (for a different reply to Fodor and Lepore, see Pagin, 1997). The results in logic about compositionality bear on this debate. Debates between Zdrozny, Hintikka, Hodges and Westerståhl have shown that compositionality does not by itself constrain the meaning of logical languages (see also Fodor & Lepore, 2001).

Compositionality has also been used in the debate around the nature of concepts. Fodor has argued that compositionality is inconsistent with most psychological and philosophical theories of concepts (Fodor, 1998a, 1998b, 1998c; Fodor & Lepore, 1996). As he puts it (1998a, p. 104): “compositionality is a sharp sword that cutteth many knots.” It is now common to distinguish two arguments from compositionality.

The first argument says, as a first approximation, that save for a finite number of exceptions, whoever possesses the concept of  $x$  (or understands  $\lceil x \rceil$ ) and the concept of  $y$  (or understands  $\lceil y \rceil$ ) is able to entertain the concept of  $x$  that is  $y$  (or understands  $\lceil x \text{ that is } y \rceil$ ). To use Fodor’s (in)famous example, whoever possesses the concept of pet and the concept of fish is able to entertain the concept of pet fish. This is supposed to be inconsistent with how concepts are individuated according to current psychological and philosophical theories of concepts. For instance, if concepts are recognitional capacities (or, *mutatis mutandis*, if concepts are prototypes, or are individuated by means of their functional role, etc.), one should be able to recognize pet fish, when one possesses the concept of pet and the concept of fish, which is not the case – or so Fodor argues. It is often replied that complex concepts do not have to be similar to simple concepts. For instance, complex concepts do not have to be recognitional, even if simple concepts are.

The second argument, sometimes called “the argument from reverse compositionality,” is supposed to rebut this reply. Fodor argues that necessarily, whoever possesses a complex concept *X THAT IS Y* (or understands the complex expression ‘*x that is y*’) possesses the concepts *X* and *Y* (or understands ‘*x*’ and understands ‘*y*’). For instance, necessarily, whoever is able to entertain the concept of pet fish possesses the concept of pet and the concept of fish. But, if a complex concept does not have to be recognitional even when its constituents are recognitional, one could entertain a complex concept, without entertaining its constituents, which is impossible – or so Fodor claims. Many papers have critically engaged in these two arguments (e.g., Robbins, 2001, 2002; Prinz, 2002, chapter 12; Recanati, 2002; Werning, 2002; Peacocke, 2004). Notice, importantly, that in this context, “compositionality” is taken in a slightly different sense. Instead of bearing on meaning, it concerns the properties that are constitutive of concepts or of the possession of concepts.

Several articles in our two volumes focus on these issues. Markus Werning’s paper critically reviews the three most commonly cited reasons for compositionality – productivity, systematicity and inferentiality – and looks for alternative justifications. Menno Lievers critically discusses the arguments for Evans’ Generality Constraint. Denis Bonnay relies on Hodges’ formal approach to compositionality (Hodges, 2001) to argue for molecularism, roughly, the idea that the meaning of an expression is determined by its use in some meaning-fixing sentences. Pierre Jacob provides a detailed criticism of Fodor’s compositionality argument.

Interestingly, several articles deal with other philosophical topics connected to compositionality. Alda Mari’s paper, at the intersection of formal ontology, metaphysics and linguistics, focuses on the nature of groups. Hannes Leitgeb examines formally how similarities could compose – which is of interest both for philosophers of science and for cognitive scientists. Kenneth Gemes’ article belongs to the philosophy of science. Gemes shows how the content of a theory can be compositional, meaning that it can be broken up into natural content parts. These content parts are of special importance for the empirical confirmation of theories by empirical evidence. Finally, Verena Gottschling’s article and Pierre Poirier and Benoit Hardy-Vallée’s article belong to the philosophy of psychology. Gottschling focuses on the nature of the content of perceptual representations. Poirier and Hardy-Vallée focus on what they call the spatial-motor view of cognition, in brief the idea that we are thinking with analogical representations.

### ***Psychology***

“Compositionality” is used in a slightly different way in psychology. Since the ground-breaking article by Osherson and Smith (1981), there has been a lot

of experimental and modelling work on how people create complex concepts (for reviews, see Hampton, 1997; Murphy, 2002, chapter 12). Roughly, the idea is that people in long-term memory have some bodies of information, i.e., concepts, about categories like dogs, tables, and so on. However, people do not, in long-term memory, have any concepts for categories like small dogs, square tables, Harvard graduate students who are carpenters, and so on. Rather, we are on the fly able to create a concept for, say, Harvard graduate students who are carpenters out of our concepts of Harvard graduate students and of carpenters, which themselves are stored in long-term memory.

Research on this topic in psychology is indifferently called “concept composition” or “concept combination.” In this context, “compositionality” is usually used to refer to the fact that a complex concept  $XY$ , for instance the concept of graduate students who are carpenters, is created exclusively on the basis of the concepts  $X$  and  $Y$ , for instance the concept of graduate students and the concept of carpenters. When this is not the case, for instance because we rely on our background knowledge to create a complex concept, psychologists often speak of compositionality violations.

In the eighties, Smith and colleagues’ selective modification model (Smith, Osherson, Rips, & Keane, 1988) attracted a lot of critical attention (Murphy, 1988). Hampton’s work on the relation between prototypes and concept combination is also noticeable (Hampton, 1987, 1988). In the nineties, new models were developed. Of particular interest were Wisniewski’s model and the model developed by Costello and Keane (Wisniewski, 1996; Costello & Keane, 2000; see also Gagné & Shoben, 1997). To a large extent, this psychological work is continuous with the work in linguistics concerning how people understand complex expressions, particularly noun-noun compounds like “dog newspaper” (e.g., Levi, 1978).

Three articles in our two volumes focus on the psychological issues connected to compositionality. Nick Braisby investigates how his own view of concepts, the Relational View of Concepts, deals with the composition of concepts. He argues that his model, partly inspired by the so-called classical view of concepts, deals well with some problematic cases of concept composition. Building on their model (2000), Costello and Keane examine why the understanding of noun-noun compounds (such as “cow spoon”, “grass bird” or “rose gun”) seems to be non compositional. They insist on the importance of pragmatic factors in linguistic understanding. In his article, George Dunbar comes to a similar conclusion. He provides some empirical evidence that the comprehension of noun-noun compounds depends centrally on pragmatic factors.

### ***Brain and cognitive modelling***

Cognitive science, including neuropsychology, is by and large representationalist. It assumes that cognition consists in manipulating representations. Of course, there is room for disagreement concerning the nature of these representations. Famously, Fodor and Pylyshyn (1988) have argued (1) that compositionality was a necessary property of our mental representational systems and (2) that in connectionist models, representations did not possess this property. In this context, “compositionality” refers to a host of properties – primarily to the capacity to produce structured complex representations out of simpler representations. This article fuelled an intense research on how to model representational systems, particularly among connectionists.

This work has progressively merged with the modelling and experimental efforts in computational neuroscience. Models in cognitive neuroscience have particularly focused on what is known in this field as the binding problem (von der Malsburg, 1981; see the issue of *Neuron*, 24, 1, 1999). Roughly, the binding problem is the following: How to represent the co-instantiation of properties? To use a simple example, the binding problem consists in explaining how the brain represents the fact that a unique object is both red and square by contrast to the fact that an object is red and another is square. To deal with the binding problem, experimental and modelling work has focused particularly, but not exclusively, on neural oscillations and on synchronous signals.

Two contributions in our two volumes bear on these issues. Ralf Garionis analyzes the properties of generative models in the context of unsupervised learning. Frank van der Velde describes the main properties of the model he has been developing with Marc de Kamps – what he calls “a neural ‘blackboard’ architecture of compositional sentence structure” (van der Velde and de Kamps, forthcoming). This model particularly addresses the binding problem.

Because of their true interdisciplinary nature, many papers gathered in our two volumes cannot be clearly identified with a specific academic discipline. Most of these papers are at the intersection of two and sometimes three disciplines. To illustrate, several articles are at the border of linguistics and psychology. Braisby’s, Costello and Keane’s and Dunbar’s papers bear equally on how people create complex concepts and how people understand noun-noun compounds. Indeed, they are explicitly inspired by the literature in both fields. Hodges’, Westerståhl’s and others’ result are increasingly used outside logic. Bonnay uses their approach to bear on the philosophical issues about the nature of meaning (see also Peregrin’s and Cohnitz articles). Mari’s and Mateu’s articles are at the intersection of linguistics and philosophy. Gottschling’s and Poirier and Hardy-Vallée’s articles are at the intersection of philosophy and psychology. And so on.

It is obvious that “compositionality” is not always used with the same meaning in all these disciplines and that there is room for misunderstanding between and sometimes within disciplines. We attempted above to pin down some of these differences in the use of “compositionality.” It remains that across disciplines, there is plenty of convergence on some issues connected to compositionality. It is our hope that these two volumes will foster new exchanges across the disciplines of the cognitive sciences.

Düsseldorf and Pittsburgh, July 2005

E.M., G.S., & M.W.

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