Does the Principle of Compositionality Explain Productivity? For a Pluralist View of the Role of Formal Languages as Models

Ernesto Perini-Santos

Departamento de Filosofia, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
eperinisantos@gmail.com

Abstract. One of the main motivations for having a compositional semantics is the account of the productivity of natural languages. Formal languages are often part of the account of productivity, i.e., of how beings with finite capacities are able to produce and understand a potentially infinite number of sentences, by offering a model of this process. This account of productivity consists in the generation of proofs in a formal system, that is taken to represent the way speakers grasp the meaning of an indefinite number of sentences. The informational basis is restricted to what is represented in the lexicon. This constraint is considered as a requirement for the account of productivity, or at least of an important feature of productivity, namely, that we can grasp automatically the meaning of a huge number of complex expressions, far beyond what can be memorized. However, empirical results in psycholinguistics, and especially particular patterns of ERP, show that the brain integrates information of different sources very fast, without any felt effort on the part of the speaker. This shows that formal procedures do not explain productivity. However, formal models are still useful in the account of how we get at the semantic value of a complex expression, once we have the meanings of its parts, even if there is no formal explanation of how we get at those meanings. A practice-oriented view of modeling gives an adequate interpretation of this result: formal compositional semantics may be a useful model for some explanatory purposes concerning natural languages, without being a good model for dealing with other *explananda*.

Keywords. Compositionality, Productivity, Modeling, Contextualism

1. Introduction

The principle of compositionality (PC) can be presented roughly as follows:

> **Principle of Compositionality**: the meaning of an expression is a function of the meanings of its parts and of the way they are combined.

As it is well known, PC is underspecified in many respects: it requires a specification of what counts as a part, what is the syntax of the language and what is the relation "is a function of". Moreover, PC is also part of distinct explanatory projects, from the learnability of a language to the determination of the meaning of its complex expressions, pointing at different sources of evidence, from psychology to intuitions concerning the semantic value of linguistic expressions.[1] A central *explanandum* of PC is productivity:

> **Productivity**: PC explains how a potentially infinite output can be generated from a finite basis.

This is still underspecified: it may be used to explain the learnability of a language, as it is the case famously in Davidson's approach, or the capacity of a speaker to produce a potentially infinite number of sentences, or of an interpreter to understand also indefinitely many sentences. I will be interested mainly in the capacity of understanding. We should also take notice of the fact that, as it is also often remarked, it is not necessary to postulate a potentially infinite output. The crucial point is that an interpreter cannot memorize the huge number of sentences she is able to grasp, their understanding has to be generated from a limited basis, through a limited number of steps.

It is clear that recursivity is at least part of the explanation of productivity: speakers cannot memorize the meaning of each individual sentence they are able to understand, they get at the intended reading by recursive operations on sub-sentential components, as required by PC. We should ask however whether such operations can generate the intended reading of sentences, in other words, if the interpretation of sentences can be represented exclusively by syntatic operations on their sub-sentential components. A compositional account of productivity is precisely the idea that the reading of a sentence is generated exclusively by formal operations taking as input its sub-sentential components and returning its intepretation. For Borg, for instance, this account seems to be quite straightforward:

> First, I think a formal theory of meaning has a crucial role to play in explaining how we can learn and understand a natural language. <…> The best explanation for the generative nature of our linguistic understanding seems to be that the meaning of complex wholes must be determined by the meanings of their parts and their mode of composition. For if this is the case, then it is no mystery why our understanding of complex linguistic items has an indefinite range — for all we need to know are the meanings of a (finite) set of primitives and recursively specified rules of composition operating on those

[1] On the different interpretations of PC, see [19], 153-156; see also [17], [18], [25].

> primitives. And this is what a formal theory tells us knowledge of meaning is like: it's a recursively specified theory operating over a finite set of primitives (roughly, words).[2]

This use of a formal system makes it a model of the process by which speakers produce and understand complex expressions. The claim that only formal operations on lexically encoded information can explain productivity has been an important argument in the opposition to contextualism in philosophy of language. Indeed, the contextualist claim that all sorts of information can have an effect on the understanding of what is said by a given utterance runs counter to this explanation of productivity.

But are formal systems an appropriate tool to explain productivity? We have empirical reasons to think that the mind integrates information from different sources in processing sentences, and does it very fast and incrementally. For this reason, the formal generation of proofs is not a good model to the way the speakers grasp a huge number of sentences from a finite basis. That does not mean formal languages are not good models for natural languages *simpliciter*: they may serve certain explanatory purposes, without being useful to other purposes of the theory. More precisely, the compositional account of productivity, that is, the generation of the intended reading of sentences exclusively by formal operations of lexically encoded information is not a good model to the way speakers get at the interpretation of sentences.

2. Formal languages as models

At first, we may describe a formal language as a model by taking it to be a simplified construct selecting features of a target system (a natural language) that are considered to be relevant to the explanation of a certain behavior of this system (e.g., its productivity). The mere formal representation of a natural language by a formal language is not enough to see how it provides this account. In the formal theory, the intended readings of sentences are generated as proofs in an axiomatic system. This formal way to generate a potentially infinite output from a finite input is taken to be a model of the way speakers do it.

In order to see how this account works, let us we take a look at a particular problem for which compositional explanations have been suggested. Consider the sentences:

i. John started a car
ii. John started a cigarette.

Aspectual verbs require the complement to denote an event, and therefore in (i), it is said that John started the running of an engine, and in (ii), that he started to smoke a cigarette. The meaning of the verb coerces its complement to have a particular meaning in the sentence, distinct from the usual meaning of the word. At first, this seems to

[2] [4], 56-57. To some, it seems to be the only possible account; see, e.g., [24], 7-8.

be a problem for a compositional account, since the contributions of *car* and *cigarette* to what is said by (i) and (ii) are not independent of the sentences in which they figure, and therefore they cannot provide an independent basis on which the compositional process of understanding can build.

However, there are compositional ways to get the correct interpretation of the sentences, by a process known as coercion. Coercion occurs when there is a mismatch between the types of the words in a sentence. In Asher's account, given a type mismatch within a sentence, an accommodation process is triggered, changing the denotation of the complement of the verb to an appropriate type, in this case, from an object to an event. The accommodation of type presupposition takes place in the construction of the logical form and is guided by information included in the lexicon. No other information is needed, and recursive operations on lexically encoded information leads to the appropriate interpretation of sentences, just as it is expected if PC is to offer an account of productivity. The interpretation is then represented in a proof-theoretic framework.[3]

Why should we want to build every information used in the interpretation of (i) and (ii) into the lexicon?

> Are such coercions really part of lexical *semantics*? That is, is it a defeasible but *a priori* inference that if John started the car, John started the engine of the car or that if Julie enjoyed the book, then (defeasibly) she enjoyed reading it? Do such inferences follow solely from one's linguistic mastery of the language? Fodor and Lepore think that none of these inferences belong to lexical semantics but are rather part of encyclopaedic or world knowledge. However, most people can distinguish between the largely automatic interpretations that these predications seem to entail and those that require more conscious effort. One might take that to be a mark of the information as being present even during predication rather than inferred afterwards using background, nonlinguistic beliefs.[4]

The information used in the interpretation of (i) and (ii) has to be part of the lexical semantics, and be treated compositionally, in order to explain the fluidity of their interpretation. While this is not exactly the productivity *explanandum*, that makes no claim concerning the phenomenology of understanding, it is quite close to it: we want to explain not only how speakers understand a huge number of sentences from a finite basis, but how they do it without any conscious effort. Why only lexically based interpretations can account for the automatic reading of sentences? Is it the case that any information that is not encoded in the lexicon leads to a slow processing of sentences? How do we know that?

---

[3] [3]

[4] [3], 15. The other reason for a positive answer is simply that the formal system generates the intended reading of sentences in which coercion occurs; of course, this result itself does not explain the phenomenology of interpretation.

Davidson has a rather direct explanation for the connection between productivity and compositional semantics: only a compositional theory of meaning explains how finite minds can understand an infinite number of sentences.[5] How does it work? According to the "Davidsonian program," a compositional theory of meaning puts "someone who understands it in a position to understand any sentence of the language for which it is a theory." [6] A theorist, having an axiomatic representation of the meanings of terms of a given language, will be able to the generate the interpretation of every sentence of this language in proof-theoretic way. However, the Davidsonian approach doesn't address directly the fluidity of interpretation. Why should the amount of effort demanded of the theorist be of any interest to explain the processing of sentences? While it may be true that, for the theorist, taking account of world knowledge slows the process of generating the interpretation of sentences, we have to ask whether this also holds for subpersonal processes involved in our understanding of language.

We may consider that the automacity of the interpretation is accounted for by an algorithm, that will take as input only lexically encoded information and deliver the required interpretation. In a sense, the automaticity of interpretation simply is the existence of such an algorithm, and Asher gives precisely an algorithm for the accomodation of types in the construction of the logical form of sentences, providing thereby an account for the automaticity of the interpretation of (i)-(ii). However, the mere existence of an algorithm does not assure that the process will require no conscious effort on the part of the interpreter. A more substantive claim is needed, namely, that the formal approach mirrors what goes on in the mind of the interpreter, as she grasps a sentence: the processing of sentences implements the suggested algorithm leading to the intended readings.[7] This more substantive claim amounts to viewing the algorithm used to produce the intended interpretation as a model for the process of understanding sentences that takes place in the mind of interpreters. Asher's theory for the coercion phenomenon may very well be a correct model for coercion. However, I am interested in the general motivation of a formal theory as the *explanans* of productivity. Asher wants to build every piece of information used in the interpretation in the lexicon in order to explain why it is felt as effortless by the interpreter, as opposed to the conscious effort demanded by the consideration of world

[5] Although Davidson's argument starts with learnability conditions, it deals mostly with the understanding of sentences.

[6] [16], 17-18. As Davidson himself puts it, "one natural condition to impose <on what it is to know a language> is that we must be able to define a predicate of expressions, based solely on their formal properties, that picks out the class of meaningful expressions (sentences), on the assumption that various psychological variables are held constant. This predicate gives the grammar of the language. Another, and more interesting, condition is that we must be able to specify, in a way that depends effectively and solely on formal considerations, what every sentence means." [5], 7-8.

[7] I thank Antonio N. Coelho for the discussion of this point.

knowledge. The general claim is that whenever information that is not plausably represented as lexical information is taken into account in the understanding of a sentence, the hearer feels the process of interpretation as demanding more effort. We should ask whether this a motivated claim.

3. Is there anything else in the target system?

It is clear that the account of productivity is at least partially compositional: there is a recursive component in language that is part of the explanation of how we produce and understand a potentially infinite number of sentences from a finite basis. The problem however is to know whether the interpretation of a sentence "depends effectively and solely on formal considerations," as Davidson puts it, or, as Ludwig and Lepore say, "an axiomatic truth theory for a language of the right sort contains all the information that we need to meet the goals of providing a compositional meaning theory for a language."

This constraint is independent of the Davidsonian take on the relation between a theory of meaning for a language and productivity. It is also Asher's requirement, grounded in the phenomenology of understanding: the use of any information not encoded in the lexicon will slow the process of interpretation. Also for him, the reading of a sentence has to be generated formally, as a proof, that will take as input only what is represented in the meanings of the terms, and return its logical form. The formal procedure is a model for the automatic process of understanding. Here is a version of this Automatic Interpretation (AI) requirement:

> **(AI)** The automatic interpretation of sentences is explained if, only if, their understanding uses only information that it is plausibly encoded in the lexicon.

This is part of the formal account of productivity: only a formal procedure can explain the way we understand any, or at least many new sentences never encountered before, without any conscious effort, from a finite basis, and this formal procedure can take in only lexical information. Should we accept (AI)?

Before addressing this question, a couple of remarks. Firstly, the workings of the mind are not transparent to the subject. It may be true that it is harder to a theorist to take account of world knowledge, as compared to building proofs in an axiomatic system, whether it is taken to represent the meanings of the terms of a sentence or not, and the latter is an automatic process, while the former is not. But what goes on at a personal level does not represent the way subpersonal processes deal with the same kind of information. Moreover, the fact that a formal system is able to generate an indefinite number of sentences from a finite basis is not in itself an explanation of the way we, as speakers of a language, do it. As said above, a more substantive claim is needed – and, in this case, it is a claim concerning the mechanism leading to a certain

phenomenology of understanding, i.e., the opposition between the interpretation of sentences felt as automatic and those demanding a conscious effort.

There are other routes to know what goes on in the mind of the speaker as she grasps a sentence. An important kind of evidence that the mind uses different sources of information, including world knowledge, in the understanding of a language, comes from psycholinguistics, in particular from two distinctive event-related potential (ERP) patterns measured in the processing of sentences. There is a negative deflection in the electrical activity in certain areas of the brain that peaks at around 400 *ms* after the onset of semantically anomalous words (N400), and a positive peak around 600 *ms* after the onset of words hard to integrate in the syntax of the sentence, but also with the expected thematic role (P600).

The N400 effect is particularly relevant here. It appears at the onset of the words in italic:[8]

- The Dutch trains are *white*...[9]
- Every evening I drink some *wine* before I go to sleep.[10]
- I think that euthanasia is an *acceptable* course of action.[11]
- The ham sandwich left without paying.[12]

In (iii), the effect is due to the background knowledge that Dutch trains are yellow. Smaller, but clear N400 effects are elicited by (iv), when uttered by a child, and by (v), when evaluated by someone who doesn't think that euthanasia is an acceptable course of action. Interestingly, (vi) does not lead to the N400 effect when said in a appropriate context, but it takes place when uttered in an unfavorable setting.

In all those cases, the understanding taps into world knowledge, but doesn't lead to a conscious effort of interpretation. The same effect is elicited by the vision of incongrous pictures[13] and in the integration of incongruous co-speech gestures.[14] This is also the case in coercion, that elicits an N400 effect.[15] The mere fact the N400 is identified doesn't preclude a compositional account of coercion such as Asher's. But, on the one hand, an algorithm such as the one offered for (i)-(ii) doesn't seem to be avail-

[8] "The N400 was first described at the sentence level: in 1980, Kutas and Hillyard demonstrated a more negative N400 to words that were semantically anomalous versus congruous with their preceding sentence contexts, such as to the word "socks", in the sentence, "He spread the warm bread with socks." <…>. The amplitude of the N400 was subsequently shown to be modulated by a variety of factors other than frank semantic anomaly. <…> across sentences, van Berkum, Hagoort and Brown demonstrated that words that are acceptable within a sentence, but incongruous with their global discourse context, also evoke an N400 effect." [11], 24.

[9] [11]

[10] [22]

[11] [23]

[12] [20]

[13] [11], 44.

[14] [10]

[15] [2]

able for (iii)-(vi). On the other hand, if coercion doesn't demand any conscious effort and if its processing has the same pattern in the brain as the processing of (iii)-(vi), which clearly includes world knowledge, then we have no reason to think that the mere fact that world knowledge is needed to get at the intended reading will lead to a harder path to interpretation as felt by the interpreter.

According to one interpretation, N400 and P600 combined show that the process of understanding "engages at least two interactive but dissociable routes or streams to comprehension," a semantic-memory route, involving both stable and more contextually bound expectations, and a route sensitive to "morphosyntactic as well as to thematic–semantic constraints." Neither stream uses only lexical or syntatic information.[16] While there is still lot of debate around these two effects, (AI) does not seem well motivated: there is a fast integration of different sources of information in the interpretation of sentences, that, from the phenomenological point of view, seem automatic. Although a formal system may generate an indefinite number of sentences from a finite basis, which is one of the *explananda* of PC, it doesn't mirror the way we do it. It is precisely at this juncture that a practice-oriented view of models opens up new ways of seeing the relationship between formal theories and natural languages

4. Another look at formal languages as models

It is not always clear what formal compositional accounts are supposed to explain. Dowty, for instance, justifies the claim that the compositionality of natural languages is "beyond any serious doubt" using arguments deriving from productivity.[17] He is certainly right in arguing for the compositionality of natural languages from the balance between finite storage and the grasping of a potential infinite number of sentences, and also in thinking that the specific theory to be adopted is an empirical matter.[18] But then he goes on to say that "ultimately the only empirical test of a model-theoretic account of natural language semantics is the characterization of *entailments among sentences* it gives."[19] Of course, we may also think there are empirical reasons for accepting a specific theory for the way speakers of a language with finite capacities grasp a potentially infinite number of sentences other than the characteriztion of entailment patterns – for instance, data coming from psycholinguistics. What is going on here?

Let us take a look at a couple of other semantic theories. In Jaszczolt's Default Semantics, PC holds at a level unifying different sources of information, that she calls

[16] [10], 44. For a single-stream theory explanation of language processing accommodating these effects, see [5].
[17] [7], 23-24.
[18] [7], 27-28.
[19] [7], 40.

the *Principle of Compositionality for the Merger*:

The meaning of the act of communication is a function of the meaning of the words, the sentence structure, defaults, and conscious pragmatic inference$_1$.[20] There is no formal derivation of the meaning of the merger. Default information, as well as conscious pragmatic inference$_1$ (i.e., pragmatic contributions to truth-conditional content), are not incorporated in the merger by formally described mechanisms.[21]

This is also the case for some recent accommodations of contextualist examples in formal versions of the Principle. In Recanati's version, the contextualist PC reads:

$I(a*b)_c = f((g((I(a)_c), (g(I(b)_c)))$

where *g* is a "pragmatic modulation function" made salient by the context:

> Thus understood, the formula says that the interpretation (content) of a complex expression a*b is a function of the modulated meanings of its parts and the way they are put together (and nothing else).[22]

The contextualist PC doesn't say anything about the way we get at the modulated meanings of subsentential components of sentences. This also holds for Dekker's Live Principle of Compositionality:

The live meaning of a compound expression is a function of the live meanings of its parts and their (live) mode of composition.[23] A live interpretation "is one that interlocutors, and a suitably informed observer, can agree upon."[24] Dekker goes on to give many of contextualists' favorite cases as examples of live meanings. Again, there is no formal way to get at the interpretation agreed upon by interlocutors.

What is the point of having such a weak reading of PC? The reason is that it can explain systematicity, or at least some aspects of it. More precisely, PC has a role in explaining how we keep track of the intended interpretation in a given discourse. In Dekker's example, although it is clear that in sentences like (vi), uttered in an appropriate context, *ham sandwich* refers to a person, not to a sandwich, the following sentence is not a felicitous one:

ix. The ham sandwich wants to pay for it.

Likewise, even if we could back (vi) by an explanation such as

x. The ham sandwich is the person who ordered the/a ham sandwich,

(xi) does not seem to be a felicitous utterance:

xi. ? The ham sandwich is the person who ordered the/a ham sandwich.[25]

[20] [14], 72.

[21] "To repeat, although such merger representations are compositional, on the level of the information pertaining to the particular sources no compositionality is expected. In other words, just as linguistic semantics is not compositional, the meaning conveyed through cognitive or social–cultural defaults, or through pragmatic inference, is not compositional either: compositionality can be found at the level of their merger." [14], 98.

[22] [17], 189.

[23] [6], 54.

[24] [6], 54.

[25] [6], 65-66.

In all those cases, there is a compositional explanation of the semantic value of the sentence, once we get at the intended readings of its parts, but no formal account of how we get at those interpretations. In other words, there is no compositional account of productivity.

There are at least two different sorts of *explananda* here. On the one hand, productivity, that is, an explanation of how speakers solve the balance between a small input and a large output in the understanding and production of sentences. On the other hand, how the semantic value of a complex expression depends on the value of its parts and the way the are combined. This is what is aimed at by a semantics keeping track of contextually modulated meanings of expressions, what seems to be a common thread in the theories mentioned above. According to Lasersohn, most semanticists are not interested in modeling "what people do, on-line, in real time, as they are speaking and listening", but only in how "grammar assigns interpretations" – and, indeed, grammar does it compositionally.[26] He is right in distinguishing these two problems, and I don't have an assessment of what semanticists usually take themselves to be doing. It's clear, however, that Asher's phenomenological motivation for building compositional account of coercion only makes sense if he takes himself to model "what people do, on-line, in real time, as they are speaking and listening." Moreover, I am not sure that saying that "grammar assigns interpretations" compositionally is a good description of the contextualist PC, as suggested by Recanati and Dekker, nor of Jaszczolt's Default Semantics.

Be that as it may, once we keep apart these two *explananda*, we can understand better Dowty's claim that "the only empirical test of a model-theoretic account of natural language semantics is the characterization of *entailments among sentences* it gives". This is a plausible approach (at least *prima facie*) to the semantic value of complex expressions, but not a good way to ground empirical claims about productivity. We can make sense of this double evaluation of PC if we see models as epistemic tools, that may be put to different uses – as a matter of fact, many features of formal languages as modeling devices make more sense. To begin with, the manipulability constraint is something to be expected in the construction of models:

> As epistemic tools models are constructed in the light of certain scientific questions and they make insightful use of available representational means and their characteristic affordances. From this perspective models function as external tools for thinking, the construction and manipulation of which are crucial to their epistemic functioning.[27]

We are reminded, of course, of the Davidsonian idea that an axiomatic theory should put "someone who understands it in a position to understand any sentence of the language for which it is a theory." Notice however that, also for Asher's proposal, the compositional account follows this manipulability condition: we learn precisely how to generate the reading of sentences using his formal system.

[26] [15]

[27] [11], 263.

Moreover, the fact that a model is an epistemic artifact, as Knuuttila also says,

> <...> implies first, that human agency, or rather traces of it, are more or less manifestly present in it. Second, it implies that models are somehow materialized inhabitants of the intersubjective field of human activity. Third, it implies that models can function also as knowledge object.[28]

Formal languages are, of course, materalized inhabitants of our world that may be the object of inquiry in themselves. More importantly, insasmuch as we are interested in models as representational devices, we should understand their relationship with the world not as a two-place relationship, but as a more complex relationship involving the agent who uses models, roughly with the form:

> *S* uses *X* to represent *W* for purposes *P*.[29]

Formal languages may be used to represent natural languages for certain purposes, and not for others. This approach of modeling gives a better understanding of the way formal languages can be part of a theory for natural languages. Instead of asking whether natural languages have a compositional semantics or not, we should look for different explanatory purposes for which a given formal model may be useful.

5. Conclusion

Modeling the generation of the interpretation of sentences as a formal process is not a good strategy, for the strict informational basis on which such models are built does not represent the larger pool of resources used by human mind in processing sentences. But formal modeling may be useful for other purposes, such as the explanation of how of we keep track of different readings of a word accross sentences or within a sentence, or, more generally, how the semantic value of a complex expression is explained, once we have the meanings of its parts, even if there is no formal explanation of how we get at those meanings. The problem not in the use of formal models for natural languages, but in having a too strict take on the relationship between models and their targets, instead of a more open view of the modeling practice. There is no simple answer as to whether language can be represented by a compositional mechanism or not, we should ask rather which is the explanatory purpose of giving a certain formal model for a given language. A practice-oriented view of modeling gives a better perspective on the different uses of PC: formal compositional semantics may be a useful model for some explanatory purposes concerning natural languages, without being a good model for dealing with other *explananda*.

[28] [12], 1487.
[29] [8] 743.

References

[1] Asher, N., *Lexical Meaning in Context* - A Web of Words, Cambridge University Press, 2011.

[2] Baggio, G., Choma, T., van Lambalgen, M., Hagoor, P., Coercion and Compositionality, *Journal of Cognitive Neuroscience* 22:9. (2009), 2131–2140.

[3] Borg, E., *Minimal Semantics*, Oxford University Press, 2004.

[4] Brouwer, H., Fitz, H., Hoeks, J. Getting real about semantic illusions: rethinking the functional role of the P600 in language comprehension. *Brain Research*. 446 (2012), 127-143.

[5] Davidson, D., *Inquiries into Truth and Interpretation*, Clarendon Press, 1984.

[6] Dekker, P., The Live Principle of Compositionality. In: Gutzmann, D., Köpping, J., Meier, C. (eds.) *Approaches to Meaning*, Brill, 2014, 45-84.

[7] Dowty, D. Compositionality as an Empirical Problem. *In* Barker, Ch., Jacobson, P. (eds.) *Direct Compositionality*. Oxford University Press, 2007, 23-101.

[8] Giere, R. How Models Are Used to Represent Reality . *Philosophy of Science* (2004), 71, 742–752.

[9] Hagoort, P., van Berkum, J. Beyond the Sentence Given. *Phil. Trans. R. Soc*. B, 362 (2001), 801–811.

[10] Hagoort, P., Hald, L., Bastiaansen, M., Petersson, K. M. Integration of word meaning and world knowledge in language comprehension. *Science*. 16;304(2004), 438-41.

[11] Knuuttila, T., Modelling and representing: An artifactual approach to model-based representation. *Studies in History and Philosophy of Science* (2011), 42, 262–271

[12] Knuuttila, T, Voutilaine, A. A Parser as an Epistemic Artifact: A Material View on Models. *Philosophy of Science*,70 (2003), 1484-1495

[13] Kuperberg, G., Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research*, 2007, 1146, 23–49

[14] Jaszczolt, K., *Default Semantics*, Oxford University Press, 2005.

[15] Lasersohn, P. Contextualism and compositionality. *Linguistics and Philosophy* **35** (2012), 171-189.

[16] Lepore, E., Ludwig, K., *Donald Davidson's Truth-Theoretic Semantics*. Oxford University Press, 2007.

[17] Pagin, P., Westerstahl, D. Compositionality I: Definitions and Variants. *Philosophy Compass* **5** (2010), 250–264

[18] Pagin, P., Westerstahl, D. Compositionality II : Arguments and Problems. *Philosophy Compass* **5** (2010), 265–282

[19] Partee, B. *Compositionality in Formal Semantics*, Blackwell, 2004.

[20] Recanati, F., Flexibility and Context-Dependence. *In* Wernig, M. Hinzen, Machery, E. (eds.) *The Oxford Handbook of Compositionality*, 2012, Oxford University Press, 175-191.

[21] Schumacher, P. *The Hepatitis Called*… Electrophysiological evidence for enriched composition. *In* Meibauer, J. and M. Steinbach (eds.) *Experimental Pragmatics/Semantics*, 2011, John Benjamins, 199-220.

[22] Schumacher, P. When combinatorial processing results in reconceptualization: toward a new approach of compositionality. *Frontiers in Psychology*. **4** (2013), 1-13.

[23] Schumacher, P. Content and context in incremental processing: ‘‘the ham sandwich’’ revisited. *Philosophical Studies*. **168** (2014), 151-165

[24] Stanley, J., *Language in Context*. Oxford University Press, 2007.

[25] Szabó, Z. S. The Case for Compositionality. *In* Wernig, M. Hinzen, Machery, E. (eds.) *The Oxford Handbook of Compositionality*, 2012, Oxford University Press, 64-80.

[26] Van Berkum, J. J. A., van den Brink, D., Cathelijne M. J. Y., Tesink, C. M. J., Kos, M., Hagoort, P. The Neural Integration of Speaker and Message. *Journal of Cognitive Neuroscience* **20**:4 (2008), 580–591.

[27] Van Berkum, J. J. A., Holleman, B., Nieuwland, M. S., Otten, M., Murre, J. Right or wrong? The brain's fast response to morally objectionable statements. *Psychological Science*, **20** (2009), 1092 -1099.