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Laure Vieu (cf. cover)

Introduction

Searching for the categorization of spatial entities in language and cognition*

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1. The categorization of spatial entities in different research fields

1.1 Categorization

Any research field needs to classify entities and phenomena into categories. Indeed, categories and "kinds" have been the center of much attention at least since Aristotle. Studying "what there is" is even the main objective of ontology, a branch of metaphysics in philosophy, which strives at providing evidence for how the world is organized into categories of entities and at formally characterizing these categories. Linguistics and cognitive psychology are also centrally concerned with

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categorizing phenomena, when observing linguistic structures and regularities in the former case and traces of cognitive processing in the latter case. Artificial intelligence has recently focused on the need to develop knowledge representations that are based on well-founded generic categories in order to better guarantee knowledge reusability and interoperability. In these cognitive sciences an abundant literature shows that the importance of the spatial domain is nowadays largely established. Nevertheless, the basic issue of how to categorize *spatial entities* has not been sufficiently stressed and thorough discussions of this topic are still missing. This book is an attempt to fill in this gap.

We should add a word concerning our use of the term "spatial entity" in this volume. We view these entities as having a spatial extension, that is to say as occupying a certain portion of space at a given point in time and as potentially serving to locate other individuals in space. Thus, "spatial embodiment" constitutes an important property of spatial entities that differentiates them from individuals that are more tightly related to other domains such as time, thoughts, or emotions.

1.2 Previous work

In linguistics the descriptive research that has been carried out about the spatial lexicon during the last decades has mainly focused on spatial "relations", that is to say on the markers (e.g., verbs, prepositions, cases) that specify the static or dynamic relationships among (spatial) entities in order to localize them (Herskovits 1986; Leech 1969; Talmy 2000; Vandeloise 1986). Scholars have shown comparatively little interest in determining the precise nature of the entities that underlie the configurations involved. This is all the more surprising that in the somewhat related domain of tense and aspect much more effort has been devoted to grasp the differences among various kinds of temporal "eventualities" and other temporal entities (see for instance Comrie 1976; Moens & Steedman 1988; Vendler 1957; Vet 1994). This trend in research on space is reflected in the fact that syntactic categories which refer more "directly" to spatial entities (e.g., nouns, adjectives, determiners) have been less studied by scholars searching for the expression of space in language. Moreover, those languages which syntactically emphasize structure/shape, position, function or other spatial properties of entities have long remained on the fringe or have even been ignored (Brown 1994; Craig 1986; Levinson 1994; see also Grinevald's paper in this volume), in contrast to the most widely used "occidental" languages, that have been the basis of most studies. Apart from some particular notions, such as the mass/count or singular/collective distinctions, which have given rise to an abundant linguistic literature (see for instance Link 1983; Parsons 1970, 1975), many oppositions have been taken for granted (e.g., animate/inanimate, natural/artifact, alienable/inalienable, mobile/immobile). These oppositions have not been deeply described nor formally defined and their use

in the literature reveals important divergences. This is the case of the alienability/inalienability distinction which, as noticed by Heine in his study of possession (1997), applies to very different situations depending on the author, e.g., a component part of an entity (leg), a spatial part (top), an element usually associated with an entity (bag), a property (whiteness). The same goes for other less frequently used concepts, whether they are borrowed from mathematics (e.g., dimensions of a figure in a geometrical space), metaphysics (e.g., object, place, location, matter, concrete/abstract, material/immaterial) or from other domains (e.g., path, trajectory). By way of example, the concepts of "place" and "path", which have appeared in the linguistic literature on space (for instance Jackendoff 1983, 1990; Talmy 2000), seem to be mostly handled in a rather intuitive way that does not allow us to provide precise (and perhaps unified) definitions.

From a neuropsychological and cognitive point of view, the debates concerning the processing of "what" and "where" information, as well as their expansion to language, should have resulted in a discussion about the properties of spatial entities in language and in cognition. However, the strong claim that localizing descriptions should mostly be based on the "where" system, rather than on the "what" system, has led researchers to neglect new debates concerning the nature of spatial entities.

In psycholinguistic and developmental research, the explosion of comparative approaches founded on a new version of the linguistic relativity hypothesis constitute another way to explore how language distinguishes entities and to examine the implications of such distinctions for the relation between language and cognition. Although this research has shown the existence of important ontological properties that had not emerged on the basis of occidental languages (for example, the shape and position of entities), this finding is still quite recent and has up to now essentially focused on the study of spatial relations.

Current developmental research on spatial language and cognition addresses a number of related questions that are at the forefront of vivid debates: What is the relative impact of universal cognitive determinants and of language-specific and/or culture-specific factors on how children represent space? Are there some prelinguistic (perceptual, sensori-motor, conceptual) prerequisites to the development of subsequent linguistic and cognitive categories? Are prelinguistic categories part of the child's innate biological endowment or are they learned – more or less rapidly – through perceptual and cognitive development after birth? How can current models of human development articulate the precocious ontological categories that are displayed by young infants during the prelinguistic period (from a few months of life onwards) and subsequent categorization patterns that appear after the emergence of language (at around two years of age)?

The research on formal ontology that has originally emerged within philosophy (metaphysics), but that is now being also carried out in artificial intelligence

and formal semantics, is first and foremost concerned with the links among categories (of entities) or domains, on the one hand, and general concepts, on the other hand. The study of the nature of spatial entities and spatial concepts has long drawn the attention of philosophers among which Descartes, Newton and Leibniz. In Husserl's program, formal ontology aims at determining how the latter (the concepts) allow us to define or to provide a foundation for the former (the entities). Contemporary formal ontology accordingly founds its research on spatial entities on Mereology, the theory of the part-of relation introduced by Lesniewski, often extended to topological concepts (Casati & Varzi 1999). Relevant and actually richer theories of categories of spatial entities are also found in formal semantics, for example, theories of the mass/count reference (Pelletier 1979; Quine 1960) or of singular and plural entities (Link 1997). It is only when applying ontology to artificial intelligence that the need for formal systems encompassing all categories – obviously including spatial entities, has become pressing, producing the so-called "top-level" ontologies (Masolo et al. 2003).

The methods and results of research in formal ontology can be quite different depending on whether the adopted perspective is "realistic", "cognitive", or "linguistic". Nevertheless, it seems to become clear that a precise analysis of the classes of spatial entities that are found in language and in cognition cannot do without formal tools that support and complement descriptive and psycholinguistic studies. More generally, the complex questions addressed here require a real interdisciplinary approach in which the results and perspectives within different fields can be integrated: descriptive linguistics, (neuro)psycholinguistics, cognitive and developmental psychology, the philosophy of language, metaphysics or artificial intelligence.

1.3 Open issues

The first question to be addressed by researchers concerned with the categorization of spatial entities is to determine whether language and cognition do or do not resort to such a classification. This question immediately requires that we consider the means that are available within each discipline to pinpoint clues for categorization: the thorough study of the relationships among forms/structures and meanings (descriptive and formal linguistics), the designing of tasks intended to detect processes of categorization ((neuro)psycholinguistics and cognitive psychology), the observation of (ir)regularities in inferential behavior, and the search for generality and coherence in the construction of models formalizing properties and concepts (formal ontology, i.e., philosophy and artificial intelligence). The scope of the domains that are studied within each discipline is also likely to vary: language and cognition in the case of descriptive and formal linguistics; language, vision, proprioception and other cognitive faculties for (neuro)psycholinguistics and cognitive psychology; cognition and reasoning for philosophy and artificial intelligence.

If the existence of categorization clues can be shown, many other points need to be further clarified concerning the status of the highlighted concepts and properties (unary predicates) and their organization. One central question here is to wonder whether these concepts/properties contribute to "structuring" language and cognition or whether they merely give "content" to a structure that has an independent existence. From a linguistic point of view, this issue corresponds to the opposition between grammatical/closed-class and lexical/open-class elements, the former determining structure and the latter contributing content (Talmy 2000). Moreover, are the concepts involved primitive or rather reducible to more basic notions? Are they really "essential"/"real" or do they result from a change in viewpoint concerning the same referent? Do these concepts have a universal status or do they depend on individual and cultural factors which would make them more relative? Finally, can they be restricted to the sphere of language or must they systematically have an extralinguistic, cognitive or metaphysical dimension? For instance, one may well ask if the mass/count or singular/collective distinctions that are made in language always have a counterpart in cognition or even in "reality". This list of points aims at illustrating the range and complexity of the questions raised by the possible categorization of spatial entities in language and cognition, and obviously does not intend to be exhaustive. It is also important to note that these points are interrelated in many respects. For example, the possible essential status of concepts is not unrelated to their primitive or complex nature and these two aspects themselves bear on the relation between language and cognition, as well as on the universal or relative nature of the studied concepts.

In addition to examining distinctions among spatial entities in language/cognition and the concepts underlying them, it is also necessary to determine which theories and models are best suited to account for these phenomena and structures. Among other issues, this entails (1) modeling how the concepts and the categories to which they give rise are organized, (2) integrating the distinctions thus defined within a theory of meaning and reference, as well as (3) clarifying the interactions between language and cognition, and the processes that take place at each of these levels. These different theoretical planes and related disciplines are likely to introduce more or less formal models determined by varied constraints (e.g., coherence, minimalism, calculability, cognitive validity). Beyond possible differences among them, however, these various models and formalisms will be subjected to some adequacy requirement: descriptive and formal linguistics, together with the philosophy of language, must make sure that the obtained results accurately mirror acceptable linguistic descriptions; (neuro)psycholinguistics and cognitive psychology must endeavor to bring together theoretical predictions and experimental findings; finally, philosophy and artificial intelligence must check

that the proposed models are logically coherent and really correspond to intuitions as far as inferential behavior is concerned. Therefore, it can be seen that human activity will serve as an important reference point and will provide an empirical basis for our models and theories.

2. Towards new directions: An overview of the contents of this volume

This volume is organized in three parts tackling the many questions raised by the categorization of spatial entities from various perspectives that emerge across disciplines: descriptive linguistics (Section 2.1), psycholinguistics and developmental psychology (Section 2.2), artificial intelligence, philosophy and the philosophy of language (Section 2.3).

As will become clear throughout the volume, a distinction is consistently made between spatial entities that are "material" vs. "immaterial". Immaterial entities are often considered as closely related to material entities, whether they are occupied by such material entities or more generally defined in relation to them (e.g., a crack, a hole).[1] Immaterial individuals will receive different designations throughout the chapters: space portions, spatial referents (of entities), "spatial" entities[2]...

In addition to this basic distinction, many other properties of spatial entities emerge from the different contributions, for instance distinctions between count vs. mass, singular vs. collective, natural vs. created, mobile vs. immobile, intrinsically oriented vs. non oriented and containing vs. non containing. Beyond the importance of precisely determining and defining these properties – a task which still remains to be done (see above), an important goal of this volume is to find out which among them are likely to entail a linguistic and cognitive categorization of spatial entities.

Some of these features (e.g., fixedness, orientation, containment) illustrate the close interactions between spatial entities and their properties, on the one hand, and spatial relations/localization, on the other hand. Thus, although the term "semantic categorization" often applies here to the classification of spatial entities, it will also occasionally refer to the categorization of spatial relations that are implied

1. However, while some scholars assume that immaterial entities always depend on material ones (for instance, in the following chapters: Stosic, Choi-Jonin & Sarda, Aurnague, Champagne, Vieu et al., Vieu & Aurnague), other researchers seem to endow them with an autonomous existence (even acknowledging their strong relation with material entities; cf. Vandeloise and Muller's contributions).

2. In Vandeloise's chapter, the generic term "spatial entity" is used in a more restrictive sense and refers to immaterial individuals only.

by the properties of spatial entities (mainly in the second part of the volume). This is a further illustration of the complex interactions between spatial entities and relations.

2.1 Spatial entities and the structures of languages: Descriptive work

The first descriptive paper by Vandeloise introduces a taxonomy of basic natural entities that is illustrated with data from French and from English, but meant to have a more general linguistic and cognitive validity. The study is concerned with "material" entities (defined as "anything we can perceive independently") and mostly considers elements that are situated at the "basic" level of the taxonomy, as opposed to the level of super-entities (among which collections) and sub-entities (parts of basic entities).

Vandeloise draws a first distinction between material entities and the places they occupy, also called "spatial entities", showing the very close relations that these two categories of entities often display in language.

Second, he considers the opposition between count entities (e.g., table, dog) and masses (e.g., water, wine). In addition to the well-known properties of cumulativity and divisibility that are characteristic of masses (Pelletier 1979; Quine 1960), he discusses the different ways (specific or not) in which these two kinds of entities "delimit" other entities (Langacker 1991).

Vandeloise also points out the similarities between masses and "aggregates" (e.g., salt, sand), as well as their differences with respect to "homogeneity", which is defined as the size/grain of the elements they are made of and the possibility of individually identifying these elements (from this point of view masses would be 0-homogeneous and aggregates d-homogeneous). It is argued that in each language a bordeline D exists such that every d-homogeneous aggregate with $d>D$ can be designated by a plural noun (e.g., *épinards* ('spinach')).

After analyzing super-entities characterized as collections (and their relationships with aggregates), Vandeloise looks into the category of "mixtures" made up of more than one ingredient (contrary to masses and aggregates). He makes a distinction between "physical" mixtures (also called "assortments"; e.g., barley in wheat), "chemical" 0-homogeneous mixtures ("blends"; e.g. water in wine), and "fusions" whose components are inseparable by physical processes (e.g., hydrogen in water). He shows that the notion of "containment" – in particular the control exerted by the container on the content and the motion of the content towards the container – better accounts for some uses of the preposition *dans* ('in') involving mixtures than the concept of topological inclusion (e.g., contrast between *Le lait est dans le café* ('The milk is in the coffee') and *Le café est dans le lait* ('The coffee is in the milk')).

In her contribution Borillo analyzes the spatial meaning of the French preposition *contre* ('against'), with particular attention to how entities and force dynamics contribute to determine its semantic content. Unlike other studies which distinguish a unique spatial use of *contre* (together with other non spatial uses), her claim is that this marker denotes different spatial relations among concrete physical entities.

Several of these configurations involve the notions of "tension" and of "force"/"counterforce" which are included in the more general system of "force dynamics" (Talmy 2000). In a first series of situations, the force originates in the figure – thus playing the role of "agonist" – which can be a material solid entity subjected to the force of gravity, e.g., *L'échelle est appuyée contre le mur* ('The ladder is leaning up against the wall'), a living being endowed with intentionality and exerting a more or less intense force; e.g., *Il plaqua son oreille contre la cloison* ('He stuck his ear against the wall') or any agonist generating a force in a "dynamic" way. In this last case, the dynamic force can result in a strong impact, e.g., *Le fauve se précipita contre le grillage* ('The wild beast rushed against the wire fence'), a violent clash, e.g., *Les balles ont ricoché contre le grillage* ('The bullets bounced against the wire fence'), or a physical deterioration of the ground, e.g., *Le vase est allé se fracasser contre le mur* ('The vase went and shattered against the wall').

A second class of configurations groups together cases where the force is exerted by the ground entity (agonist) which is usually a "natural" dynamic element (e.g., flowing water, rain, waves, wind, fire, thunderstorm, tempest). The counterforce opposed by the figure ("antagonist") can remain passive or defensive, e.g., *La digue est une protection contre les vagues* ('The sea-wall is a protection against the waves'), *Il s'abrita contre le vent* ('He sheltered against the wind') or can work in a more dynamic fashion, e.g., *Le saumon nage contre le courant* ('The salmon swims against the stream').

The third kind of spatial uses of *contre* calls for the concept of force/counterforce and corresponds to cases in which entities of the same class simultaneously exert opposite forces. This type of situation is often expressed by means of reciprocal constructions such as *les uns contre les autres*, e.g., *Les verres cliquetaient les uns contre les autres* ('The glasses clinked against each other'), *Elle frotta ses mains l'une contre l'autre* ('She rubbed her hands one against the other').

Finally, three spatial uses of *contre* seem not to be directly associated with the concept of force dynamics (perspective effect of contact and proximity, visual contrast, direction and facing position).

In the following paper, Stosic considers two other French prepositions, *par* ('by') and *à travers* ('through'), that are closely related to the expression of dynamic space. The paper aims at grasping the semantic constraints that are imposed by these markers on the nouns with which they are combined (ground entities). It takes as a starting point the classification of spatial entities that is used in other

contributions of this volume (see, for instance, Choi-Jonin & Sarda as well as Aurnague, Champagne, Vieu et al.'s papers) and that was initially proposed for the analysis of static space.

An analysis of corpora focusing on uses of *par* describing "paths", as in *Il est passé par le jardin* ('He came through/by the garden'), shows that this preposition can be mainly combined with nouns of two types: nouns denoting particular kinds of space portions called "apertures" (contingent apertures, e.g., *trou* ('hole'), *fente* ('crack, split') and functional apertures, e.g., *porte* ('door'), *fenêtre* ('window')); nouns referring to various types of "locations", such as geographical locations (e.g., *le jardin* ('the garden'), *Bruxelles* ('Brussels')), roads (e.g., *rue* ('street'), *chemin* ('path')), or entities designated by Internal Localization Nouns (ILNs; e.g., *fond* ('bottom'/'back'), *côté* ('side')). The association of *par* with nouns identifying "objects" (e.g., *table* ('table'), *tasse* ('cup')) is much more problematic – except for those objects characterized as "pipes" (e.g., *tuyau/conduit* ('pipe'), *paille* ('straw')) – and it is excluded for nouns of substances. On the basis of these various observations, the author concludes that in its path-type uses *par* selects (as grounds) entities which define a space portion and are able to establish a "connection" between some other entities of the motion event (the considered grounds are often stable elements).

Just like *par*, *à travers* ('through') accepts to be combined with nouns of apertures. However, in contrast to *par*, this preposition does not require the presence of a space portion, since the aperture can be closed up by a material entity. Even with an opened aperture, the preposition seems to highlight the fact that the figure passes between the (material) boundaries delimiting the space portion, rather than its motion through this space portion. *A travers* can also be associated with nouns of locations, but in this case it focuses on the motion of the figure within the location/ground (the figure may remain there all the time there) and does not imply any connection of the ground with other entities belonging to a possible path (moreover connecting entities belonging to the category of roads usually do not occur with *à travers*). Finally (and contrary to *par*), nouns of material objects and substances can perfectly play the role of ground when combined with *à travers*. The author concludes that the preposition *à travers* neither needs the presence of a space portion in the ground, nor implies that this entity must establish connections with other entities involved in the motion event. Rather he proposes to capture the semantics of *à travers* by means of the concept of "guidance" calling for the two notions of "force dynamics" (Talmy 2000) and of "lateral orientation" (Vandeloise 1986).

Without questioning the classification of spatial entities proposed in other static studies, this analysis completes the panorama of the spatial entities that are differentiated in language, in particular by introducing the categories of "roads" (subclass of locations) and of "pipes" (subclass of objects). The significance of

the former category is confirmed by other observations in Choi-Jonin and Sarda's work (see below).

The fourth paper by Grinevald gives an overview of some non Indo-European languages that overtly categorize spatial entities by using classifiers and, more generally, nominal classification systems. The lexical origin of classifiers is first emphasized together with their more or less grammaticalized behavior: a consequence of this bivalent status is that classifiers seem to stand midway between lexicogenesis and morpho-syntax. Four main subtypes of classifiers are then distinguished – noun, numeral, genitive and verbal classifiers – which can be related to predominant "semantic profiles", e.g., noun classifiers → material/essence of entities, numeral classifiers → physical dimensions, genitive classifiers → use/function. Classifiers can be also characterized according to their degree of specificity, which can range from cases of unique classifiers (only one element in the class) or repeaters (homophonous with a noun) to general de-semanticized systems (large heterogeneous classes), through the most common type of specific classifiers (classes built around prototypical exemplars). The author underlines additional factors that might differentiate classifiers (degree of grammaticalization, age, productivity, areal status) and mentions other classification systems which also call for properties of spatial entities (e.g., posture verbs known in Amerindian and (some) European languages, positionals of Tzeltal). As a conclusion of this first typological presentation, it is claimed that classifier systems have to be studied through a multidimensional approach and fieldwork methodology associating semantics, morpho-syntax and discourse.

A sample is then provided to the reader. Numeral classifiers are illustrated by means of selected data from both large size/discourse use systems (Burmese, Tzotzil) and very grammaticalized ones (Chibchan languages). Noun classifiers whose semantic motivation is closely related to the material nature or essence of entities are illustrated by the case of Jakaltek Popti'. Concerning genitive classifiers, inventories from Oceanic languages and from Panare reveal important similarities about the functional distinctions that these systems operate among entities. Finally, it is showed that, in several languages (Haida, Ika, Kwakwala), verbal classifiers point to physical/spatial characteristics of entities which are very similar to the properties identified by numeral classifiers.

In the third part of her paper, Grinevald reviews the main parameters that seem to condition the way in which information on spatial entities are expressed in language. She indicates that this kind of information can be overt, covert or unspecified and may be distributed through various elements of the clause: class terms, numeral, noun or genitive classifiers, verbal classifiers, posture satellites, body part locatives, relational nouns. . . The conveyed properties can focus on different aspects of entities – shape/dimension/orientation (color is never encoded), function, material/essence – and seem to mainly call for visual and tactile perception modes (olfactory and auditory modes appear not to be involved). Moreover some kind of convergence and overlapping often emerges between different types of information (e.g., shape and function) or different categories of markers (e.g., numeral and verbal classifiers). In conclusion, it is indicated that some languages of the world (in particular, Amerindian and Australian ones) really "obsess" about spatial information and spatial entities.

The last contribution of the descriptive part focuses on "orientation" motion verbs of Korean and French. Choi-Jonin and Sarda analyze the semantic content of these verbs and their interaction with "functional" suffixes (locative, ablative, directional, accusative in Korean) and prepositions (*à*, *de*, *vers* in French), as well as their behavior in other specific constructions (e.g., direct constructions). They first show that Korean dynamic descriptions often consist of a motion verb denoting "Motion" and "Path" (according to the terminology proposed by Talmy 2000) and a deictic (motion) verb expressing "Motion" and "Deixis". At first sight, Korean orientation verbs can occur with all functional suffixes. The situation seems to be more complex in French, where (apart from the preposition *à* 'at') not all orientation verbs can combine with all prepositions.

However, it is necessary to go beyond verbs and suffixes/prepositions and to consider the nature of the entity ("object entity") that is identified by their associated grammatical object. Three important outcomes of this analysis can be highlighted. First, both in Korean and in French lexical units designating objects and locations behave in different (and often opposite) ways. Moreover, Internal Localization Nouns (or "relational nouns"; e.g., *ɥi/haut* ('top'), *ap^h/avant* ('front')) appear to be much closer to nouns of (specified) locations than to nouns of objects. This strengthens the opposition between objects and locations (and the close link of ILNs with the latter category) that results from analyses of the prepositions *par* (cf. Stosic's work) and *à* (cf. Aurnague, Champagne, Vieu et al.'s paper). Second, direct constructions of French calling for vertical orientation verbs, e.g., *Paul monte/descend l'escalier* ('Paul is moving up/down the stairs') (as well as accusative constructions of Korean deictic motion verbs *ka-ta* 'go' and *o-ta* 'come'), confirm that spatial entities classified as roads can give rise to a specific type of linguistic processing (corresponding to some extent to Stosic's conclusions). Third, it is possible to explain many mismatches in the kinds of nouns that are selected by Korean or French verbs and suffixes/prepositions by virtue of the presence of a deictic motion verb in the Korean constructions. This point nicely illustrates the complex interaction between aspectual-temporal properties, on the one hand, and properties of spatial entities, on the other hand.

However, the central outcome of this paper is the proposal that the Path component of dynamic descriptions (Talmy 2000) should be split up into three notions: "Path of motion" (motion towards the interior/exterior, the top/bottom: Korean and French motion verbs), "Path of localization" (final or initial position

of the figure: Korean locative and ablative, French prepositions *à* and *de*) and "Path of trajectory" which can be itself broken down into "Path of total trajectory" (Path and Ground conflated: Korean accusative, French direct object) and "Path of partial trajectory" (Path and Ground not conflated: Korean directional, French preposition *vers*).

In short, the descriptive work presented in the first part of this volume seems to indicate that language does not handle spatial entities indiscriminately, but rather makes some significant distinctions among them. At the same time, partial answers are provided to the questions raised in Section 1.3.

Thus, while nouns of entities probably convey important categorizing properties in their semantic content, these features usually come to light when these nouns are combined with appropriate grammatical elements. For example, quantifiers and determiners lead to distinctions between count entities and masses (possibility/impossibility of using a numeral quantifier) or between plural and singular aggregates (possibility/impossibility of using a plural; see Vandeloise's paper). Such "direct" or "overt" markings of categories can also be found in classifiers and more generally in nominal classification systems across many languages over the world (see Grinevald's paper). However, an important outcome of the present descriptive analyses is to show the existence of a more "indirect" or "covert" – but not less real – classification of spatial entities on the basis of the selectional restrictions of some spatial expressions (most of which denote spatial relations), whether they are lexical elements (e.g., motion verbs) or more grammaticalized units (e.g., spatial prepositions, cases). For instance, as already mentioned above, the analysis of the French preposition *par* (Stosic's paper) and the comparative study of Korean and French utterances combining motion verbs with suffixes or prepositions (Choi-Jonin and Sarda's paper) show that entities characterized as objects or locations cannot be equally used as grounds. The same markers and constructions also indicate that Internal Localization Nouns behave very much like nouns of locations (see also Aurnague, Champagne, Vieu and colleagues' paper in Part II). If we now also take into account data from Basque genitives (Aurnague 2004) or from Longgu locatives (Hill 1996), a general notion of location (as opposed to the notion of object) emerges on the basis of properties such as the (relative) stability/fixity of an entity, the presence of a space portion, knowledge about the localization of the entity in question (for specified locations)... Although they are less directly encoded because of their covert nature, notice that these properties and distinctions are often related to grammatical markers (e.g., prepositions, cases) or to constructions containing closed-class elements (e.g., verb + preposition/suffix) and that they are therefore likely to play a structuring role in language and cognition.

Now are these properties real/essential characteristics of entities? Are they objectively present in the reality out there in a such a way that speakers would be always compelled to grasp them? Although the studies presented in this first part of the volume adopt a referential approach, most of them presuppose a state of affairs that is subjected to perception and conceptualization, that is to say a "perceived reality" (as opposed to an objective one). Such a "reality" is usually grasped in a quite stable way by speakers due to their common perceptive and cognitive endowment (Kleiber 1997). This makes collective actions and particularly linguistic communication possible. According to this approach, the distinctions among spatial entities that are (overtly or covertly) made by some linguistic markers will lead speakers to apply the corresponding constraints to entities as represented in the perceived reality. But inasmuch as different markers and constructions can highlight different properties of entities, a referent fulfilling several of those sets of conditions can be classified in more than one category. So, linguistic distinctions among spatial entities seem to operate as "filters" allowing different points of view on the same entity rather than as rigid and unchanging categorizations in the reality out there. As suggested in Vandeloise's paper, a forest includes a space portion and can be viewed as a location where it is possible to move (e.g., *Le bourdon vole dans la forêt* ('The bumblebee is flying in the forest')) but an appropriate expression can also emphasize its pure material facet (e.g., *une haute forêt* ('a high forest')). In the same way, Stosic shows that entities which have the properties of apertures can often be associated either with the preposition *par* (e.g., *L'air froid entrait par le trou de la serrure* ('Cold air was coming in through the keyhole')) or with the preposition *à travers* (e.g., *Un rai de soleil filtrait à travers les fentes du volet* ('A ray of sunshine filtered through the slits of the shutter')). However, whereas the former marker (*par*) focuses on the presence of a space portion and on the possibility for the ground to establish connections with other entities (the ground is thus really conceived as an aperture), the latter (*à travers*) underlines the material limits of the ground (via the concept of "guidance") and regards it as any kind of (material) object. A last (classic) example from Burmese quoted in Grinevald's paper indicates that the numeral classifiers of this language can describe the very same spatial entity (e.g., a river) in a variety of ways (e.g., a line on a map, an arc/path to the sea, a connection between villages, a thing), the choice of a particular point of view being often conditioned by pragmatic factors such as situational context.

Of course the descriptive papers of this first part do not pretend to answer complex questions such as whether the distinctions among spatial entities are universal versus culture-dependent or whether they necessarily depend on language or involve a more general extra linguistic or cognitive dimension. However, these analyses bring some light to these questions. For instance, the cross-linguistic observations about the opposition between locations and objects (see above) and the recurrent finding that Internal Localization Nouns behave as nouns of locations suggest that this distinction and the properties it calls for (stability/fixity, existence

of a space portion. . .) may have a universal cognitive status. The same thing could be probably said of the category of apertures which plays a role not only in the use of the French preposition *par* (by), but also in the semantics of numeral (physical) classifiers in Burmese (cf. Grinevald's paper). Nevertheless, several other data found in this volume remind us that linguistic and cultural factors are likely to condition the distinctions among entities that are made in a given language, as well as the relative "saliency" or "weight" attributed to them. In this way, we pointed out that in French nouns of apertures can be selected by both *par* and *à travers*, still highlighting different properties of these entities (space portion/aperture versus material limits; see above). In comparison, the same nouns systematically combine with the Serbian preposition *kroz* ('through'): its semantic content is similar to that of *à travers* (Stosic 2002) and thus focuses on the material nature of the ground entity (via the notion of "guidance"), rather that on its aperture-like properties (e.g., existence of a space portion, "connector" entity). Other examples are provided by the variable borderlines (related to the size/grain of elements) that languages set for distinguishing between singular and plural aggregates (e.g., *épinards/spinach*) (see Vandeloise's paper) or by the presence of a deictic component (deictic motion verb) in many dynamic descriptions of space in Korean (see Choi-Jonin and Sarda's paper).

To sum up, the descriptive studies presented in the first part of this volume show that a careful semantic analysis of markers is all the more necessary that the linguistic distinctions among spatial entities are not always overt and can often be more covert. This kind of analysis also leads us to specify the content of the underlying concepts and distinctions (for instance, the fact that the notion of location is grounded on properties such as fixity and the existence of a space portion), partially answering the question of their complex or primitive nature mentioned in Section 1.3. However, it is clear that a more comprehensive definition of the conceptual structures underlying the linguistic categorization of spatial entities implies a close coordination with formal research in artificial intelligence, philosophy and the philosophy of language (see Section 2.3).[3] Indeed, such collaborations have already proven to be successful for the study of spatial markers (see for instance Asher & Sablayrolles 1996; Aurnague, Vieu, & Borillo 1997). Among other things, they showed that functional concepts such as support or containment are governed by complex common-sense theories and they also made it possible to specify the relationships between functional and geometrical aspects of spatial relations.

3. Note that a better understanding of the ways in which concepts are structured and organized should have implications for questions concerning, among other things, their universal versus culture-dependent and linguistic versus extralinguistic/cognitive nature.

2.2 Spatial categorization in language and cognition: Psycholinguistic and developmental studies

The papers in Part II present the results of psycholinguistic studies examining the relation between linguistic and cognitive categories. A first paper by Aurnague, Champagne, Vieu et al. focuses on the different factors that may influence the intrinsic or deictic interpretations of spatial markers, with particular attention to the French Internal Localization Nouns (hereafter ILN) *avant/devant* ('front') (also see Aurnague 1996; Borillo 1988, 1999). An experiment examines how French adults interpret these markers in two tasks. In the first subjects had to point to the part of the entity that corresponded to an ILN on a tactile screen. In the second they had to judge whether or not an ILN corresponded to the portion of an entity that had been highlighted on the screen. Spatial entities varied along several dimensions, including geometrical properties (an aerodynamic shape, a salient side) and static/dynamic functional properties (e.g., "letting in" through the door, motion). The results show that all of these dimensions affect subjects' interpretations, but to different extents, according to the following hierarchy: static function > aerodynamicity; static function > saliency; dynamic function > aerodynamicity or saliency. Some differences in subjects' interpretations of French *avant* and *devant* also suggest that they associate *avant* with dynamic functions and *devant* with static functions.

Aurnague et al. conclude that ILNs refer to space portions and denote stable parts, unlike components nouns that also denote stable entities but cannot refer to space portions. They put forth the hypothesis that ILNs and component nouns should be placed on a synchronic and diachronic continuum, and that the former derives from the latter through a process of grammaticalization. Furthermore, they compare the different factors that may or may not systematically lead to the emergence of classes of spatial entities. First, context-dependent factors (aerodynamicity, geometrical saliency) are less likely to result in such a categorization than factors involving the intrinsic properties of entities (static or dynamic functions). In addition, ILNs and component nouns differ with respect to their status as grammatical and lexical elements. Component nouns constitute an open class of lexical units selecting functional properties that apply to a relatively narrow range of entities. In contrast, ILNs constitute a semi-closed class of markers that enter into larger grammatical constructions and involve a limited number of internal properties applying to a large range of entities. ILNs are therefore better candidates as powerful vectors of semantic and cognitive categorization, since grammaticalization is tied to a process of abstraction that shows a preference for a restricted set of general properties over a wide range of specific parameters (also see Heine, Claudi, & Hünnemeyer 1991; Talmy 2000).

The remaining papers in this part all address questions that are vividly debated by theories of child development: What is the nature of children's knowledge of spatial entities? By what mechanisms do their spatial categories emerge and/or change during development? What is the relation between linguistic and prelinguistic knowledge during this process? According to some views (Carey & Spelke 1994; Hespos & Spelke this volume; Leslie 1994; Spelke 2003; Spelke et al. 1992), children are born with a set of concepts that constitutes the basic core knowledge upon which spatial categories are founded. Through language children then establish connections among knowledge components and discover which conceptual distinctions are most relevant in their particular environment. In contrast, Piagetian theory posits that general underlying cognitive mechanisms drive children to construct concepts following a universal sequence of stages that is based on sensori-motor development. Yet other models (e.g., Lécuyer, Rivière, & Durand this volume; Mandler 1988, 1992, 1998) view early concept learning as resulting from active perceptual processes that lead children to extract regularities from their environment. Finally, relativistic views (Bowerman 1996a, 1996b, this volume; Bowerman & Choi 2001, 2003; Hickmann 2003a, this volume; Slobin 1996, 2003, 2006) propose that language-specific properties deeply affect how children construct categories. Despite universal cognitive determinants, languages provide filters that channel incoming information, thus making different aspects of reality more salient and accessible.

In discussing these different theoretical frameworks, the chapters examine a large age span, focusing on two fundamental aspects of children's knowledge of spatial entities. The first one concerns the emergence of the very concept of an object, which implies knowledge of basic properties such as spatio-temporal stability ("object permanence"). This crucial landmark in cognitive development has been well-studied, but the mechanisms underlying its emergence are still debated. Second, several chapters examine children's understanding of topological spatial relations, which have been at the center of most debates concerning the relation between pre-linguistic and (general or specific) linguistic categories in development. As noted above, such spatial relations are highly relevant to the present volume because they involve implicit classifications of spatial entities. For example, notions such as contact, support, containment, attachment, or joining imply an understanding of various entity properties and dimensions characterizing their use and behaviors, all of which contribute to concepts and classes of spatial entities (geometrical and functional properties of entities that can be containers, material vs. immaterial entities, volumes, surfaces, intrinsic orientation, animacy, cause, force, motion, gravity. . .).

Overviews of relevant research throughout Part II show some evidence for universal cognitive mechanisms. Recurrent developmental progressions and errors during the acquisition of spatial markers suggest that children rely on their

own concepts to talk about entities or their locations before they acquire the conventional means to do so. In contrast, Bowerman reports evidence for the impact of language particulars on children's categorization of spatial entities. For example, English and Korean differ in the particular entity properties they highlight when expressing spatial relations: "tight" vs. "loose" fit is salient in Korean (e.g., the tight-fit verb *kkita*), containment and contact/support in English (e.g., *in* vs. *on*). Accordingly, as soon as children use spatial markers (before two years) and even in earlier comprehension, they distinguish containment vs. support in English (ignoring the tight/loose distinction) and tight vs. loose fit in Korean (ignoring containment/support) (but see divergent results in Hespos & Spelke this volume). Finally, some evidence (Casasola 2005; Casasola & Cohen 1992; Choi, McDonough, Bowerman, & Mandler 1999) shows that prelinguistic English learners are sensitive to tight vs. loose containment, but do not spontaneously extract abstract "support" or "tight-fit" properties. Nonetheless, they can learn these dimensions if they are exposed to words in relevant contexts. Thus, some spatial categories are learned by direct mapping to pre-existing concepts, but others by a linguistically mediated construction process.

Following Gentner (2003), Bowerman argues that language is a special tool for prompting comparisons between exemplars in the extraction of abstractions. Further evidence from children's errors shows different types of overextensions across languages. For example, children use the verbs *open* in English and *open[-maken]* ('open[make]') in Dutch to denote canonical situations (actions on doors, boxes, etc.), but they overextend these verbs to a variety of other situations to express separation as a means of making something accessible (turning on a light, taking the stem off an apple, a piece out of a jigsaw puzzle, a shoe off a foot, etc.). In contrast, Korean learners rarely produce such overextensions, using a large variety of distinct verbs to denote different types of separation depending on particular types of entities (e.g., *ppellita* 'separate two parts symmetrically, *phyelchita* 'spread out a flat thing', *ttutta* 'tear away from base', *ppayta* 'remove from tight fit'). Similarly, from about two years on English learners use *out* vs. *off* to distinguish removal from containers and from surfaces (taking toys out of a bag vs. a lid off a pan). Dutch makes a similar distinction (*uit* vs. *af*), with the major exception of clothing items (*uit* in Dutch, *off* in English). Dutch learners accordingly abstract a general "removal" meaning, massively overgeneralizing *uit*.

Bowerman attributes these differences to the breadth and composition of categories across languages. Whereas Korean children must critically recognize entity properties to talk about "opening", English invites children to generalize broadly to many acts of separation, prompting them to ignore different entity properties. Similarly, Dutch children overgeneralize the same marker to all types of removal situations, whereas English learners do not do so. Learning spatial words and constructing underlying categories of spatial entities involves a process of comparison.

Languages lead children to proceed in one of two directions (abstraction or differentiation), thereby influencing how they organize categories of entities and events by extracting from adult use the common properties of situations.

Within a similar framework Hickmann summarizes the results of several experiments focusing on how French and English speakers (adults and children of three to seven years) express spatial information when locating entities, describing object displacements, and narrating spontaneous motion. The results from the first two tasks show that French speakers of all ages heavily rely on the verb to express spatial information and focus on particular types of information, such as the specific manner whereby figures are attached (e.g., *accrocher* 'to hook') or the general spatial and/or functional "disposition" of figures in relation to grounds (e.g., *couvrir* 'to cover'). French children first use relatively neutral verbs (e.g., *mettre* 'to put', *être* 'to be') and progressively more specific verbs. Young French children also overextend the preposition *sur* ('on') to vertical relations in the absence of contact (where adults use other prepositions: *au-dessus* 'above', *en-dessous* 'under') and to non-prototypical contact/support (where adults use neutral *à* 'at/to' or no preposition at all). In contrast, in all situations English speakers heavily rely on verbal satellites and their specific verbs focus on other types of information, such as posture (*to sit, to lie on/in*) or manner of causing location changes (*to push together/into*).

Qualitative results further show the impact of entity properties on speakers' responses. In both languages some dynamic situations elicit the greatest reliance on verbs expressing manner of attachment, as well as figure/ground properties, particularly in French (*recapuchonner* 'to put the cap (on a pen)'; *emboîter*, *encastrer, imbriquer,* all variants of the meaning 'to in-fit'). In addition, some situations present particular problems to French speakers, for example those that involve immaterial entities and part-whole relations (English *a crack in/on a cup*, *a handle on a door*). In these cases French subjects do not localize the figure but rather identify it and they have difficulty determining the figure (e.g., *une tasse fêlée* 'a cracked cup', *la poignée d'une porte* 'the handle of a door'). Such results further suggest that particular ontological properties affect the ways in which speakers perceive entities and therefore express relations among them. They deserve attention in further cross-linguistic research, since they may be related to a greater concern with some entity properties in French as compared to English.

Finally, when English speakers describe spontaneous motion, they systematically encode manner and path information at all ages (e.g., *to run up/down, across*). In contrast, French children typically use verbs to encode path (*monter/descendre* 'to go up/down', *traverser* 'to cross') and occasionally manner (*courir* 'to run'), sometimes providing information separately across clauses (*il court . . . il traverse* 'he is running. . . he is crossing'). Results also show an increase with age in the joint expression of manner and path in both languages, suggesting a growing capacity

to encode multiple information components. Nonetheless, language differences are quite striking at all ages. In line with partially relativistic hypotheses (Berman & Slobin 1994; Bowerman 1996a, b, this volume; Bowerman & Choi 2001, 2003; Slobin 1996, 2003, 2006), these studies show the impact of typological constraints on the locus of spatial information and on the focus of subjects' attention.

In sharp contrast to these two papers, Hespos and Spelke summarize a series of experiments testing the hypothesis that infants possess a rich set of conceptual distinctions independently of language. These experiments are based on two paradigms, classically used in research with prelinguistic infants. In the first ("habituation" and "reaction to novelty") children are shown different exemplars belonging to a class A until they lose interest for these stimuli (familiarization phase, decrease in exploration time). When they are then shown stimuli of class A or of another class B (test phase), interest for B-stimuli (increase in exploration time) shows a categorical distinction. In the second paradigm ("preferential looking"), children are first familiarized with stimuli of type A, then presented with pairs of stimuli B and C, only one of which is coherent with A. Interest for the incoherent stimulus indicates a surprise reaction that is based on knowledge of underlying categories.

A first series of experiments tested whether five-month-old English learners have some knowledge of the distinction between "tight" vs. "loose" fit. Infants were presented with object displacements (e.g., placing an object into a wide vs. narrow container or onto a support) that involved loosely- vs. tightly-fitting entities in containment vs. support situations. Results show that they were sensitive to the tight/loose distinction, even though it cross-cuts the category boundaries that are available in their surrounding language. Additional experiments test five-month-old infants' expectations about motion in situations involving two tightly- or loosely-fitting entities (one placed within another, constituting a wide or narrow container) that were made to move horizontally either together (coherent motion for tight fit) or separately (coherent motion for loose fit). Infants expected entities to move together in tightly-fitting situations, but separately in loosely-fitting situations, a result which is in line with previous findings showing that five-month-old infants have knowledge of mechanical entity properties (e.g., Spelke et al. 1992). A final set of experiments examined similarity judgments produced by English-speaking adults. When rating the similarity of two events, subjects differentiated containment vs. support situations, but not tight vs. loose fit. However, they were able to make the latter distinction in a forced-choice task (choosing which of two events is more similar to a third one) that invited them to pay more attention to this distinction.

Hespos and Spelke conclude that systems of core knowledge give rise to a set of spatial and mechanical concepts that is much larger than the one encoded by any one language. Infants come equipped with such core knowledge at birth and their

task is then to select those particular concepts that are relevant to their language, a process that results in language-specific categories during subsequent stages of development (also see Spelke 2003). Nonetheless, sensitivity to other concepts can be recovered easily, even in adulthood, but only if these concepts are relevant in particular situations.

Finally, Lécuyer et al. propose to test empirically the predictions of three approaches to infants' early representations of objects: Piagetian theory, perceptual theories, and nativism. Two types of evidence are particularly relevant to this debate. The first concerns "object permanence", which is a fundamental milestone in human cognitive development, showing the child's discovery that objects display some inherent and independent stability in space and time. This achievement constitutes the foundation for all further concepts concerning entities. Children's "A-not-B" errors constitute the classical evidence indicating that they do not understand object permanence. Children see an object disappear at one location A, then reappear and disappear again at another location B. When asked to locate the object, they look for it at location A, where it disappeared the first time, rather than at location B, where it disappeared the second time.

According to Piagetian theory, object permanence emerges towards the end of the first year of life and it reflects the underlying development of sensori-motor activity. In this view, the child gradually realizes that objects have their own existence independently of his/her own activity. However, recent findings emerging from both perceptual and nativist models (see reviews in Lécuyer, Streri, & Pêcheux 1996; Hickmann 2003b) show that infants understand object permanence much earlier (from about three to four months of age onwards). More generally, this research shows that infants have an extraordinarily complex knowledge about the physical world that surrounds them (numerosity, temporality, spatial relations, motion, causality, agentivity, animacy, etc.). Such evidence does not support the Piagetian approach and has given rise to a tremendous debate.

Lécuyer et al. discuss a second type of evidence concerning the spatial capacities of young children with motor deficits (30-month-olds with spinal muscular atrophy) in nonverbal tasks (A-not-B searching tasks) and in verbal tasks testing children's production and comprehension of spatial prepositions (static location). In both tasks, these children show no cognitive and/or linguistic deficits and they even display a better performance than control children. These results, then, provide two (linguistic and non-linguistic) measures of children's spatial capacities in different populations, both of which suggest that motor development is not a necessary condition for the development of spatial cognition.

Lécuyer et al. propose that this evidence can be accounted for in terms of a perceptual model in which precocious perceptual development actively modifies children's representations along three levels (also see Durand & Lécuyer 2002). Representations are first a mere copy of the external stimulus. Infants then become

able to represent variations of the stimulus in a more abstract form that gives rise to categories. At the last (language-based) level the relation between their representation and the external stimulus is arbitrary. Such representations constitute the basis for the emergence of classes of entities.

In summary, then, the papers in Part II make a substantial contribution towards an account of the relation between cognitive and linguistic spatial categories, but they also raise a number of questions that must be further addressed. Aurnague et al. provide evidence for the psychological reality of linguistic analyses that take into account several dimensions of French ILNs. Convergent results from two tasks (tapping unconscious and metalinguistic processes) capture speakers' underlying spatial representations, showing a hierarchy of effects and differences across markers. New materials are necessary to determine more precisely the hierarchical relation between two crucial dimensions (aerodynamicity and saliency) that were partially confounded. Most importantly, the hypothesis that grammaticalization is a central mechanism for the emergence of semantic and cognitive categorization should be tested within a more general psycholinguistic framework, given the assumption that the use of open vs. closed or semi-closed classes should have implications for psychological processing. For example, Talmy (2000) proposes that different open-class and closed-class markers can be ranked along a hierarchy that characterizes the degree to which the encoded information is automaticized or backgrounded – and therefore less costly for cognitive processing – vs. salient or foregrounded. As noted by the authors, cross-linguistic research is also necessary to support further generalizations of their claims, for example by comparing languages that are similar or different with respect to their lexicalization vs. grammaticalization patterns.

Further questions concern child development. Some results (Bowerman, Hickmann) suggest that children construct spatial categories partly relying on their surrounding language. Note that the Korean and French data that are separately discussed in these two papers are strikingly similar in some ways. Both show a strong reliance on verbs (rather than on satellites) to encode spatial information and an implicit classification of spatial entities that reflects a concern for finely differentiating entity properties, that is not found in English or in Dutch. In sharp contrast, other results (Hespos & Spelke) suggest that children come equipped with a large set of distinctions that is independent of language.

Given many recent findings concerning infancy, it is now necessary to circumscribe the types of distinctions that can or should be attributed to children at birth. Sophisticated experimental methodologies have provided much evidence showing surprisingly precocious capacities and further discoveries are likely to add to this stock of capacities. Models that reject the assumption of a general perceptual and cognitive propensity to learn distinctions are confronted with one of two tasks: they must either provide a principled basis (independent of linguistic, cognitive,

or perceptual learning constraints) for determining which distinctions are necessarily part of children's innate core knowledge; or show that biological endowment provides children with the stock of all distinctions that can be found across all languages in the world.

Finally, Lécuyer et al.'s propose evidence for a perceptual model of conceptual development that argues against the predictions of Piagetian theory, convincingly suggesting that motricity is not the basis for all of spatial cognition and that children construct objects and object properties by rapidly extracting invariant perceptual patterns from their environment. However, further research must disentangle which capacities are innate vs. learned among all those that are necessary for the discovery of basic object properties. In addition, like Bowerman or Hickmann, they assume an active perceptual process of construction, enabling children to grasp general properties of entities (e.g., the spatio-temporal stability of objects). However, it does not address the question of language-specific effects on the particular invariant patterns that must be discovered by children when they learn object properties, including object permanence but also further distinctions beyond this initial basic concept.

Confronting these different views highlights the question of a possible linguistic mediation for spatial cognition. The linguistic structuring of cognition may result from the joint impact of general language properties and of language-specific properties. Although these two possibilities are compatible, they differ in their theoretical focus and in their methodologies: the first view assumes that general cognitive capacities are inherently dependent on language, regardless of (and notwithstanding) linguistic particulars, but cross-linguistic comparisons are necessary to show specific language effects. In addition, a major question concerns the impact of language on both linguistic and non-linguistic representations (see discussions in Gentner & Goldin-Meadow 2003). One possibility is that language has far-reaching implications for all of spatial cognition, affecting speakers' behaviors in a large variety of situations from the earliest age on. Another possibility is that language has no deep impact on cognition above and beyond our use of language itself. Many related controversial points remain open, concerning for example the timing of language effects on children's representations, the nature of non-linguistic representations, or the nature of language effects on these representations.

2.3 Characterizing categories of spatial entities: Formal ontology and formal semantics

The third part of this volume is devoted to the characterization in logical formalisms of the categories of spatial entities that play a role in language and cognition. A fundamental issue regards the relationship between linguistics, especially

formal semantics whose purpose is to analyze how linguistic expressions refer to entities and states of affairs, and formal ontology, a main objective of which is to give a logical account of the basic categories of what there is in the world. Analytical philosophy takes its roots in the philosophy of language (Frege 1892; Quine 1960), and accordingly, a widely used practice in contemporary formal ontology is to base its arguments on linguistic evidence. Even when the arguments are not based on observations and analyses of a truly linguistic flavor, they are nevertheless expressed in some natural language, and are thus somewhat dependent on linguistic structures. On the other hand, formal semantics necessarily makes use of ontological assumptions in expressing the denotations of the linguistic expressions it analyses, be they more or less explicitly stated. In fact, such assumptions are often taken for granted, that is, the categories of referents and their formal properties are not discussed at all, neither for their linguistic or cognitive appropriateness nor for their realism. For instance, even in the largely explored domain of temporal reference, some analyses make use of a time reduced to the category of instants, others use time intervals, but these choices remain too often unjustified and the properties of the chosen time (e.g., regarding linearity or density) are usually not fully described. It is therefore not always clear in both disciplines, formal ontology and formal semantics, how to untangle the dependencies between linguistic analysis and ontological analysis: which one comes first? As a result, it is legitimate to ask whether the project of formally characterizing the categories of spatial entities underlying language belongs to formal ontology and whether such a task is at all feasible. These questions constitute the topic of the first paper of Part III by Varzi.

Varzi examines the possibility of founding ontological analysis on linguistic analysis. He focuses on two traps in trying to establish what categories of entities there are on the basis of what is said in language. The "surface grammar trap" is to take at face value all the quantifications made in linguistic statements, and in particular, to consider that all nominal phrases refer to existing sorts of things. Varzi argues that, for instance, Russell's analysis of negative existential sentences involving definite descriptions (Russell 1905) shows that this approach is a trap. Perfectly acceptable sentences like *The winged horse does not exist* cannot be interpreted by the paradoxical assertion that some existing thing does not exist. Linguistic analysis should thus reveal what is the deep structure of a sentence before examining what are its ontological assumptions. For instance, Russell's analysis of definite descriptions gives the previous example the reading of its paraphrase *It is not the case that there exists one and only one winged horse*, which is arguably ontologically more "transparent". Varzi then goes on tackling the more subtle point of showing that such a strategy brings us into the "deep structure trap". The argument is based on the fact that for any questionable category of entities (in particular non-material entities like events and cracks) to which some linguistic expressions

apparently refer, one can find a paraphrase eliminating this category. For instance, events, as apparently denoted by the NP *a kiss* in *John gave Mary a kiss*, can be eliminated in paraphrases such as *John kissed Mary*. However, as Davidson argued (Davidson 1980), the linguistic analysis of verb-phrase modifiers shows that on the contrary, the deep structure of *John kissed Mary* amounts to *there is a kiss that John gave to Mary*, i.e., it introduces the category of events. Varzi claims that if both the eliminativist and the introductionist strategies can be supported, then there is no definite methodology in determining what is the "right" deep structure, and the choice is eventually based on each linguist's prior ontological assumptions. He thus concludes that linguistic analysis cannot contribute to ontological analysis.

Varzi's negative analysis judges the enterprise of finding a coherent account of the ontological categories underlying language and cognition unfeasible, and as a result, restricts formal ontology to its realist trend, which tries to eliminate any linguistic and cognitive "bias" in establishing the structure of "what there is" (Chisholm 1996; Smith 2004). There is nevertheless a different trend in formal ontology, thriving in applications to knowledge representation (Masolo et al. 2003), as well as formal semantics as the next three papers of this part show. This cognitivist and relativistic view assumes that different coherent ontological accounts of reality, as it is perceived, conceived or described, are possible; the choice of one or another account is a matter of adequacy to some objective, e.g., adequacy to a body of cognitive evidence or to some observed linguistic structures. With this view, the logical tools of formal ontology are essential to build coherent ontological systems, but cognitive or semantic studies may provide decisive input for exploring the relevant categorical and conceptual distinctions. Of course, regarding language, this approach is valid only under the hypothesis that the linguistic study of (a given) language provides a coherent body of data against which to assess the adequacy of some ontological system, which clearly contradicts Varzi's conclusions. Descriptive and formal semantics studies are certainly not a trivial matter, and results are obviously subject to discussion among scholars, but the hypothesis that language systematically – overtly or covertly – encodes in its structures a number of ontological assumptions appears to be validated by the papers of Part I. The authors of the next three papers do adopt this heavily debated hypothesis, and yet their research, situated at the intersection of formal ontology and formal semantics, yields interesting results.

Muller's paper studies the nature of spatial entities focusing on their temporal dimension and explicitly explores the adequacy of "four-dimensionalist", or spatio-temporal, ontological theory to account for a number of well-known semantic phenomena. Muller first posits his research within the ontology-language relationship debate just mentioned and describes his ontological departure points: on the one hand, mereology (Lesniewski 1927–31) and other accounts of the part-whole relations (cf. Vieu and Aurnague's next paper), and on the other, the

four-dimensionalist position (Sider 2003) with respect to the widely discussed endurant-perdurant, continuant-occurrent or object-event distinction, i.e., the position for which all concrete entities are taken to have both spatial and temporal dimensions. Muller then examines three classical linguistic distinctions or "categories of reference" (the mass/count, the singular/plural and the object/eventuality ones) and associated linguistic phenomena, in the light of the unifying four-dimensionalist ontological assumption. For instance, the distinction between objects and eventualities apparently blocks a valid reading of the sentence *A thousand boats passed under the bridge* in which there are less than a thousand boats if the same boat passed several times under the bridge. Here, we are not really counting boats, as in the standard reading, but events or "temporal slices" ("stages") of boats. The main lines of a spatio-temporal theory providing a formal account of this four-dimensionalist ontology is then presented. Within this theory, the author shows how the three examined linguistic distinctions can be accounted for. The unique domain of the theory being a set of spatio-temporal regions, instead of focusing on entities of a different nature, Muller shows that it is enough to assume different categories of predicates, with different inferential behavior. For instance, the mass predicate "gold" and the count predicate "ring" may apply to the same entity, but while "gold" is spatio-temporally dissective (any spatio-temporal part of an amount of gold is an amount of gold), "ring" is only temporally dissective ("ring" applies to any temporal slice of a ring). Lastly, Muller shows how his analyses of plural reference and of the object/event distinction can be combined into an account of plural events that yields a unified representation for all the readings of the above passing-under-boats example. The force of Muller's proposal lies in the combination of the elegance and minimality of the ontological framework and the adequacy to rendering a fair amount of linguistic data. In fact, no previous account of the passing-under-boats quantification case that gathered all its readings had been published.

The next paper by Vieu and Aurnague focuses on the role of categories in the expression of part-whole relations in French. It shows first that the classical hypothesis of the multiplicity of part-whole relations (Winston et al. 1987) is in a large part explained by the different ontological nature of the arguments. A theory formalizing the singular/plural and the mass/count distinctions is briefly mentioned; it deals with the same kind of data examined by Muller in a more classical way, that is, it is based on several ontological categories of entities: "amount of a substance", "substance" and "material object". This theory suffices to account for the "Member-collection", "Subcollection-collection", "Portion-whole" and "Substance-whole" relations, respecting their inferential behavior regarding the property of transitivity, much discussed about part-whole relations. Vieu and Aurnague then focus on the "Component-integral whole" (CIW) relation between material objects that involves the elusive notion of functionality. Only few previous

formal accounts of this arguably predominant part-whole relation (e.g., *hand-body*, *handle-door*) were available, leaving its varied (in)transitivity patterns largely unexplained. On the basis of a review of the literature on function, the authors show first that the normativity of function requires to take into account other "categories", the lexical types used to describe the entities, distinguishing, e.g., *lit* ('bed') and *meuble* ('piece of furniture'); indeed, the expression of CIW relations is sensitive to the object descriptions used. Then, a logical theory of function is proposed using the primitive property of "being functioning as a X at time t" and defining several notions of "functional dependence": generic functional dependence between lexical types and individual functional dependence between specific entities under a description. An entity x described as a X is individually functionally dependent on a y described as a Y if, generically, any X functioning as a X requires the existence of a Y functioning as a Y, and in addition, x functioning as a X requires y functioning as a Y. The direction of the dependence, from the part to the whole or from the whole to the part, and the fact that the lexical type is directly or not the one with which the generic functional dependence is encoded in the lexicon, enable Vieu and Aurnague to distinguish and define four CIW relations. The distinction of these four relations is then proced to be linguistically relevant, on the basic of data involving determinative compound nouns. Lastly, they show that their formal model is able to explain a large number of puzzles regarding the (in)transitivity of CIW, as only some combinations of the four relations yield transitivity theorems. This paper provides an example of an ontological study driven by linguistic motivations in that it shows the need to take into account in the domain a further category of entities, the (reified) lexical types, and gives an original, although quite simple, account of the notion of functional dependence. Conversely, it becomes obvious here that considering ontological notions such as dependence in a systematic way helps the linguist in enriching his/her descriptive work: linguistic studies on part-whole relations had previously considered only the dependence of the part with respect to the whole.

The last paper by Asher focuses on "types" – in fact, ontological categories – involved in the lexicon referring to the spatial domain. Building on the well-known work on the "generative lexicon" by Pustejovsky (Pustejovsky 1995), Asher gives a highly developed logical theory of complex or "dotted" types. Lexical semantic studies on copredication data have shown the need to refer to objects that are apparently ontologically incoherent, as belonging to two incompatible types. For instance, the referent for *the book* in *The book is a great piece of literature and 800pp long* appears to be an entity both abstract and concrete since the two conjunct predicates select arguments of those two types; stipulating the existence of the "dot object" of complex type INFORMATION•PHYSICAL, Pustejovsky's approach is able to give a referent to *the book* in this example. Asher proposes to apply this notion of complex type to the spatial domain, for which (Aurnague 2004) has shown

that in addition to the two categories of geographical locations (called places by Asher) and objects, there is a need to refer to "mixed entities" such as buildings, alternatively behaving as objects and as locations, for instance in Basque. After linguistically motivating in detail the need to use an ontological domain including dot objects, Asher shows how in order to be used in formal semantics, a theory of complex ontological types is to be integrated into compositional semantics, which is traditionally only governed by "functional types" (corresponding to syntactic types), and constructed by combining only the very generic type *e* for entities and *t* for truth value with the functional application operator. Asher thus allows for a number of sub-types of the general type *e*, such as PLACE and OBJECT, and uses the dot type operator • in addition to the functional application operator. The theory of complex types and the composition logic that Asher then fully develops within the lambda-calculus framework are illustrated on a number of examples of composition. Lastly, the author shows that some patterns of transitivity of the relation denoted by the preposition *dans* ('in') could be more simply handled with complex types than as has been previously proposed. Asher's paper shows how ontology, through categories (types) and constraints on how these can combine into complex types, is reflected in lexical and compositional semantics in a very rich manner. It also offers a very promising starting point to better understand the relationship between ontological categories and "lexical types" as used in (Vieu & Aurnague this volume).

The work presented in the last part of this volume, lying at the intersection between formal ontology and formal semantics, shows that, even though the very possibility of such an interdisciplinary research is still questioned (see Varzi's paper) and its methods are not yet fully established by the literature, models of how ontological theories of spatial entities integrate within a theory of meaning to account for linguistic phenomena such as those described in Part I can indeed be achieved (see the papers by Muller, Vieu and Aurnague, and Asher). But just as the papers in Part II attested to several approaches to the relationship between cognitive and linguistic spatial categories, this part reveals that the debate on what ontology is about, the "real" world or (linguistic) conceptions of the world, is still open. Varzi's results tend to conclude that a linguistic ontology is not feasible. The three other papers contrast with Varzi's in assuming that it makes sense to look for an ontology that is adequate to account for linguistic phenomena, but Muller's still does not really take issue regarding the realist – cognitivist divide. In fact, the spatio-temporal ontology developed there relies on a unique category, and has been defended by philosophers adopting a realist approach. The last two papers definitely adopt language-relativistic views, as they show the need to introduce purely linguistically motivated categories such as lexical types (Vieu and Aurnague) and "dot types" (Asher). Nevertheless, both these papers still distinguish two layers in their theories: a basic ontological layer and a lexical layer that

builds on the first. And the exact status of the basic ontological layer remains to be established: it has to be compatible with, and even ideally highly adequate to, the deep structures of a language, but does this compatibility vary according to the specific language at hand? As Muller shows, surprisingly parsimonious ontologies may prove adequate. Thus, there may be room for a universalist cognitivist approach to ontology, for which no methodology has already been proposed, apart from a few attempts at proving that the same ontology may be adequate for different languages, e.g. for French and Basque in (Aurnague 2004). We believe that the work presented in this book as a whole lays the foundations for a truly interdisciplinary study of formal systems of cognitive spatial categories, between philosophers and linguists, as well as cognitive psychologists.

3. Conclusion and prospects

Although this volume does not exhaust the questions related to the categorization of spatial entities in language and cognition, it provides a first entry into this new research domain along three main dimensions. First, the volume evaluates previous work that directly or indirectly deals with the categorization of spatial entities in a general overview of this field (see Section 1.2 above), as well as in relation to specific points within different chapters and parts. Second, some of the main questions that arise when tackling this complex topic (Section 1.3 above) are discussed in depth throughout the contributions. Third, some answers to these questions emerge from the chapters and through the interrelations that can be found across them, for instance the fact that most languages operate an overt and/or covert categorization of spatial entities and that such a categorization seems to involve both a universal basis and a significant level of variability (cf. Stosic, Grinevald, Choi-Jonin & Sarda's chapters in Part I or Bowerman, Hickmann in Part II). On the whole, then, the volume opens a new research area, providing minimal grounds for its future developments.

Furthermore, this volume contributes to the development of new approaches and methodologies in the study of the categorization of spatial entities. It shows the need to bring together a variety of data bases and methods through an approach that is both cross-linguistic and multidisciplinary (descriptive linguistics, (neuro)psycholinguistics, cognitive and developmental psychology, philosophy, artificial intelligence. . .). In addition to describing and comparing different languages, experimental and formal approaches provide some insights into the cognitive processes and concepts that underlie the ways in which we categorize spatial entities. As a consequence, the many questions that arise concerning the nature of this categorization (e.g., structuring vs. content-giving, primitive vs. complex, real vs. conceptual, universal vs. relative, linguistic and cognitive. . ., cf. Section 1.3) benefit from multiple and complementary insights that can together bridge theoretical and empirical gaps, thereby allowing us to address new questions that would not have emerged otherwise.

Finally, ongoing studies in this volume and future research about the categorization of spatial entities in language and cognition are likely to provide data and hypotheses that can contribute in significant ways to other general questions and discussions, for example they touch on the role and functioning of referential processes in language, on the universal vs. relative nature of semantic concepts, and on the properties and structure of ontologies (whether spatial or not) in human cognition.

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PART I

Spatial entities and the structures of languages: Descriptive work