Language is one of the most challenging issues that remain to be explained from the physiological and psychological points of view. As a complex system, its formal modelling and simulation present important difficulties. Models proposed up to now have not been able to give either a coherent explanation of natural language or a satisfactory computational model for the processing of natural language. To investigate natural language, we need to cross traditional academic boundaries in order to solve the different problems related to language.

This book is an attempt to connect and integrate several academic disciplines and technologies in the pursuit of a common task: the study of language. The main goal of the book is to boost the interchange of knowledge and viewpoints between specialists who, working on linguistics, biology or computation, have an interest in bringing their methods together in order to provide innovative and challenging tools and formalisms to approach and improve theories and models on languages.

The subject of this book will attract researchers from many fields who are interested in natural or artificial languages and want to enrich their scientific research with theories, methods and ideas coming from different disciplines. People dealing with linguistics, computer science, formal language theory and biology may find in this book new and challenging ideas.

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LANGUAGE AS A COMPLEX SYSTEM

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Interdisciplinary Approaches

Edited by
Gemma Bel-Enguix and M. Dolores Jiménez-López

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Contents

PREFACE

This book consists on a collection of essays written by people from different research areas that have in common their interest on language. Therefore, the chapters contained in the book have in common two important things:

- the object they analyze: *language*;
- and the way of approaching such an object: *interdisciplinarity*.

Language is a complex system. Therefore, if we want to describe, explain and process language we must consider its complex nature. From a strictly "linguistic" point of view, language is a complex system where phonetics, morphology, syntax, semantics, lexicon, pragmatics... interact in order to produce acceptable sentences. But, language is also a complex system from the point of view of its very nature. Language is a physiological, neurological and psychological object. And, of course, it is also a sociological entity.

Language is one of the most challenging issues that remain to be explained from the physiological and psychological point of view. As a complex system, their formal modeling and simulation present important difficulties. Many computational models try to explain natural language. Many cognitive models try to explain how humans process natural language. However, models proposed up to now have not been able to give neither a coherent explanation of natural language nor a satisfactory computational model for the processing of natural language. If the scope is natural language, we need to cross traditional academic boundaries in order to solve the different problems

Chapter One

Language as a Complex Dynamic System: A View from Cognitive Linguistics

Iraide Ibarretxe-Antuñano
Javier Valenzuela-Manzanares

1 The Cognitive Linguistics Enterprise

Cognitive Linguistics is a fairly new approach to the study of language which views linguistic knowledge as part of general cognition; linguistic behaviour is not separated from other general cognitive abilities which allow mental processes such as reasoning, memory, attention or learning, but understood as an integral part of it. It emerged in the late seventies and early eighties, especially through the work of George Lakoff, Ronald Langacker, Charles Fillmore and Leonard Talmy in the States, and that of René Dirven, or Dirk Geeraerts in Europe.

This paradigm started off as a reaction against the dominant generative paradigm which pursues an autonomous[1] view of language. Some of the main assumptions underlying the generative approaches

[1]The view that language is an autonomous entity goes back to Structuralism (Saussure 1915; Bloomfield 1914, 1933). In this model, the meaning of a word is

to syntax and semantics were not in accordance with the experimental data in linguistics, psychology and other fields; the commitment to the use of "formal grammars" which view languages as systems of arbitrary symbols manipulated by mathematical rules of the sort first characterised by Emil Post, is adopted at the expense of descriptive adequacy and psychological realism (see Lakoff, 1987). What Lakoff (1990, 43) refers to as "non-finitary phenomena", i.e. mental images, general cognitive processes, basic-level categories, prototype phenomena, the use of neural foundations for linguistic theory and so on, are not considered part of these grammars because they are not characterisable in this notation. It is from this dissatisfaction with the dominant model that Cognitive Linguistics was created.

Although Cognitive Linguistics as a general framework emerged in the late seventies, it is important to bear in mind two points. Firstly, some of the cognitive assumptions central to this approach are not new. Authors such as Geeraerts (1988), Jäkel (1999), Nerlich and Clarke (2001a, b, 2002) and Taylor (1995) have shown that many of the ideas that we present in more detail in this article were already in the minds of earlier philosophers, thinkers and philologists. However, this fact must not be understood as diminishing the originality of Cognitive Linguistics, but quite the opposite. As Jäkel (1999, 23) convincingly argues: "scholars of completely different backgrounds have reached the same or very similar results independently of each other", and this fact has to be taken as a confirmation for the validity of the cognitive principles postulated by this approach.

Secondly, Cognitive Linguistics is not a totally homogeneous and unified framework (see Croft and Cruse 2004; Cuenca and Hilferty 1999; Evans and Green 2006; Geeraerts and Cuyckens 2008; Ibarretxe-Antuñano and Valenzuela, in press a; Lee 2001; Ungerer and Schmidt 2006, for general overviews). It subsumes several theories that focus on different aspects of language and whose research goals are slightly different. Therefore, Cognitive Linguistics is better understood as a "linguistic movement". Among the best well-known theories, we can mention the following: *Conceptual Metaphor and Metonymy theory* (Barcelona 2000; Gibbs 2008; Lakoff and Johnson 1980, 1999; Kövecses and Radden 1998; Panther and Radden 1999; Ruiz de Mendoza 1999), *Frame Semantics* (Fillmore 1968, 1975, 1982, 1985; Petruck 1996), *Mental Spaces and Blending theory* (Fauconnier 1994, 1997; Fauconnier and Turner 2002), *Construction Grammar* (Bergen and Chang 2005; Croft 2001; Fillmore and Kay 1993; Fillmore et al. 2009; Goldberg 1995, 2006; Steels and de Beule 2005), and *Cognitive Grammar* (Langacker 1987, 1991, 2008; Taylor 2002) (see Ibarretxe-Antuñano and Valenzuela, in press b, for a brief description). Although they are different, all of these theories agree on certain epistemological and methodological principles that we describe in the following section.

determined by the language system itself, whereas people's perception, interaction and conceptualisation are extra-linguistic factors. In the Generative approach (Chomsky 1986), language is also viewed as autonomous but in a rather different way. The language faculty itself (a computational device which is said to generate the sentences of a language through the recursive rules on structured strings of symbols, assigning syntax and semantics) is viewed as an autonomous component of mind, independent of other mental faculties.

1.1 Main Epistemological and Methodological Tenets

It is very difficult to summarise in just a few words what the main theoretical ideas and empirical methods underlying a linguistic paradigm are. However, if we have to be concise in describing its foundations, we would consider the following as the main pillars of the whole cognitive linguistics movement.

Language is understood as a product of general cognitive abilities, and therefore, it is *an integral part of cognition*. Consequently, a cognitive linguist must be willing to accept what Lakoff (1990, 40) calls the "cognitive commitment", that is, s/he must be prepared to embrace the link between language and other cognitive faculties because linguistic theory and methodology must be consistent with what is empirically known about cognition, the brain and language. In other words, the difference between language and other mental processes is not one of kind, but one of degree. Consequently, not only linguistic principles must be investigated in reference to other mental faculties, but also any account of the different levels of linguistic analysis (syntax, semantics, phonology...) should ideally be carried out taking into account all of these levels simultaneously. This view of language is rather different from more formal approaches to language such as Generative Linguistics (Chomsky 1988), Fregean semantics (Geach and Black 1952), and Montague's Model-theoretical semantics (Cann 1993; Dowty et al. 1981). These formal approaches, based on a more "objectivist" philosophical tradition, understand knowledge of linguistic structures and rules as independent of other mental processes such as attention, memory and reasoning: they propose that different levels of linguistic analysis form independent modules.

Another basic theoretical tenet is that *language is symbolic in nature*. Langacker (1987, 11) starts his chapter on the general assumptions of his *Foundations of Cognitive Grammar* precisely with this assertion, namely that language: "makes available to the speaker... an open-ended set of linguistic signs or expressions, each of which associates a semantic representation of some kind with a phonological representation". Hence, language is symbolic because it is based on the association between semantic representation and phonological representation.

This association of two different poles refers to the Saussurian conception of the linguistic sign. However, it is radically different on one basic point: the arbitrariness of the sign. While it is true that there is always a certain essential arbitrary component in the association of words with what they mean, nonetheless, this arbitrariness is restricted. For cognitive linguists, language is not structured arbitrarily. *Language is motivated and grounded* more or less directly in experience, in our bodily, physical, social, and cultural experiences because after all, "we are beings of the flesh" (Johnson 1992, 347). This notion of "grounding" is known in Cognitive Linguistics as "*embodiment*" (Johnson 1987; Lakoff 1987; Lakoff and Johnson 1980, 1999)[2] and finds its philosophical roots in the phenomenological tradition (Merleau-Ponty 1962, 1963; cf. also Varela, Thompson and Rosch 1993). Its basic idea is that mental and linguistic categories are not abstract, disembodied and human-independent categories; we create them on the basis of our concrete experiences and under the constraints imposed by our bodies.

Human categorisation is one of the major issues in Linguistics. The ability to categorise, i.e. to judge whether a particular thing is or is not an instance of a particular category, is an essential part of cognition. How human beings establish different categories of elements has been discussed ever since Aristotle. The classical view on categorisation, that of Aristotle's, claims that categories are defined in terms of a conjunction of necessary and sufficient features: that linguistic analytical categories impose a set of necessary and sufficient conditions for the membership in the category. This requirement not only implies that categories have clear boundaries and that all members of a category have equal status (Taylor 1995, 25), but also that there is an abstract, general definition with which all the members of that category must comply. The cognitive approach adopts a prototype categorisation model (cf. Rosch 1973, 1977, 1978, 1983; Rosch and Mervis 1975; Mervis and Rosch 1981 and see also Kleiber 1995, for a critical overview). In this model, human categories have several types of members: the "prototype" and then a number of progressively less central members related to the former in a motivated way. The prototype is the best, most prominent and most typical member of a category. It is the example that first comes to mind when one thinks of that category. In other words, category members do not have equivalent status, some are more important or central than others. In prototype categorisation, categories are also based to some extent on what Wittgenstein (1953) called "family resemblance". This philosopher showed that necessary and sufficient conditions are not appropriate for defining the meanings of many words, and illustrated this with the impossibility of coming up with a set of necessary and sufficient conditions for all the activities that we call "games" (e.g., card games, Olympic games, a child throwing a ball...). The relations between members of a given category are like those in a family: a daughter might resemble her mother, and the mother her father, but this does not necessarily mean that grandchild and grandfather are alike. In terms of prototype theory, this means that the central member and the less central ones are not necessarily linked directly; a less central member can be included in the same category via its "resemblance" with another less central member which does have a direct relation with the prototype. In other words, category members share some properties but these are not necessary and sufficient in order to become members. Prototype theory is especially useful in the analysis of polysemy since it helps organising and structuring the different senses around a prototype meaning. The idea is that these other senses do not have to share all the characteristics of the prototype, but just some of them. For instance, another characteristic of Cognitive Linguistics is that it tries to break down the specialisations and abstractions of formalism. As a consequence, there is a tendency to *blur classical distinctions and dichotomies*: between linguistic knowledge and encyclopaedic, real world knowledge; between literal and figurative language; between synchronic and diachronic

[2]The term "embodiment" has several different interpretations in both psychological and anthropological studies (see Chrisley and Ziemke 2002; Wilson 2002; Ziemke 2003). In this paper, embodiment is always used in the cognitive linguistic tradition of Johnson's (1987) work. For a discussion on this topic within and outside Cognitive Linguistics see, Barsalou (1999, 2003), Dirven, Frank, and Pütz (2003), Frank, Dirven, Ziemke and Bernárdez (2008), Glenberg (1997), Gibbs (2003), Ziemke, Zlatev, and Frank (2007), and Zwaan (2004).

linguistics...These distinctions are not strict for Cognitive Linguistics but clines or continua.

Meanings are related to cognitive structures embedded in our patterns of knowledge and belief. They reflect the mental categories which people have created from their experiences of growing up and acting in the world (cf. embodiment). Conventional meanings arise from experience and knowledge and our complex conceptual structures are invoked in language use and comprehension, and this is why meaning is ultimately claimed to be pragmatic. Furthermore, the fact that our experience-based knowledge is present in linguistic meaning at every level implies that there is not a strict distinction between lexicon and grammar. This means that lexicon and grammar form a continuum (Langacker 1987), that they cannot be treated as autonomous modules as postulated in Chomskyan linguistics. As Langacker (1987, 3) states "Lexicon, morphology, and syntax form a continuum of symbolic structures, which differ along various parameters but can be divided into separate components only arbitrarily".

The Saussurean dichotomy between synchrony and diachrony also disappears. Many linguistic theories have accepted Saussure's (1915) attempt to free linguistics from etymological explanation. However, the study of the evolution of linguistic structures and their processes of change can lead us to a better understanding of the current use of the language and it can provide evidence of general linguistic and cognitive principles (cf. grammaticalisation theories by Brinton and Traugott (2005); Heine, Claudi and Hünnemeyer (1991); Hopper and Traugott (2003); López-Cano and Seoane (2008); Seoane and López-Cano (2008), among others).

This relation between language and experience has led cognitive linguists to study how conceptual structures or cognitive models are reflected in language. As stated above, for most cognitive linguists, there are no clear boundaries between linguistic knowledge and encyclopaedic knowledge; meaning is inherently encyclopaedic and therefore, we cannot disassociate strictly denotative aspects from connotative ones (Cuenca and Hilferty 1999, 70). *Cognitive domains* are the proof that we need to show that this disassociation is an artificial one. They are knowledge structures, mental representations about how the world is organised. As Langacker (1987, 147) points out, they are "context[s] for the characterisation of a semantic unit", that is, coherent knowledge structures that function as contexts, as frames that situate more specific concepts in their right conceptual environment.

Let us illustrate this point with one of Langacker's classic examples: the word *Monday*. *Monday*, as any other day of the week, is not "definable" without situating it in a specific conceptual environment, without a suitable conceptual domain that will help us to bring about all the necessary knowledge and information, that is, the concept of *Week*. Similar to this notion of cognitive domain, we find Lakoff's (1987) *Idealised Cognitive Model* (ICM) and Fillmore's (1982, 1985) Frame.

Another consequence of primacy being given to general cognitive abilities is the essential role of imagination. For many people, the word imagination is related to subjectivism, idealism, and relativism. Since the Enlightenment, imagination has been despised in many theories of language, because it has been regarded as a non-rational, unruly and idiosyncratic play of ideas, and therefore, unsuitable for scientific research. In Cognitive Linguistics, imagination is considered to be a basic human cognitive ability, central to human meaning-making and rationality. As Johnson (1987, 172) explains, the way we reason and what we can experience as meaningful are both based on structures of imagination that make our experience what it is. We make sense of our less directly apprehensible experiences on the basis of more directly apprehensible experiences.

Metaphor and *metonymy* are two basic imaginative cognitive mechanisms. They are not figures of speech, as they are considered by many traditional objectivist approaches (see, for example, Halliday 1985, 319-20); not even the result of a wide array of contextual implications, as proposed by Relevance theory (Goatly 1997; Papafragou 1996; Sperber and Wilson 1995, 231-37). Rather they are considered to be the means by which it is possible "to ground our conceptual systems experientially and to reason in a constrained but creative fashion" (Johnson 1992, 351). Furthermore, metaphor and metonymy are defined as "mappings" or "projections" between conceptual domains. These two cognitive devices can be distinguished because each of them establishes connections between different types of entities (Lakoff and Turner, 1989). Whereas in metaphor, the mapping is across different experiential domains (Lakoff 1993); in metonymy, the mapping takes place within the same domain. Another cognitive mechanism is conceptual integration or *blending* (Fauconnier and Turner 2002). It is a basic mental operation that creates networks of connections between several mental spaces. The final result is a blend that develops emergent meaning that cannot be derived directly from the input

spaces.

Finally, the last characteristic that we would like to mention is the *usage-based* stance that Cognitive Linguistics takes in its understanding of how language emerges, evolves and is structure (Barlow and Kemmer 2000). Contrary to the traditional divorce between linguistic competence and linguistic performance, Cognitive Linguistics proposes a system that is shaped by linguistic usage events right from the beginning, from its inception. General abstractions about language are based and stemmed from the individual and collective usage of the language.

1.2 A Multidisciplinary Approach

One of the main advantages of Cognitive Linguistics over other linguistic frameworks is its multidisciplinary nature. We mentioned in the section above that one of the tenets in this model is the cognitive commitment. However, the result is bidirectional; not only does cognitive linguistics absorb and apply new concepts and discoveries from other research areas such as anthropology, psychology, philosophy, neurology, or artificial intelligence but also do these areas adopt the methodologies proposed in cognitive linguistics (see Kristiansen et al. 2006).

Cognitive Linguistics is also becoming a referent framework in other areas close to Linguistics such as Translation (Rojo and Ibarretxe-Antuñano, in press; Tabakowska 1993), Literary Analysis (Gavins and Steen 2003; Stockwell 2002) or Psycholinguistics, especially in areas of first language acquisition (Tomasello 2003) and second language acquisition (Robinson and Ellis 2008).

In the following section, we describe three areas in which Cognitive Linguistics has been successfully applied to current research issues both within and outside linguistics.

2 Applications of Cognitive Linguistics: Three Examples

2.1 Language and Motivation

We have previously mentioned that one of the main postulates that cognitive linguists adhere to is the assumption that language is motivated and grounded in our experience. This experience comprises

our interaction with the world that surrounds us and our own characteristics as human beings. In other words, motivation is a complex concept that includes biological, physical, social and cultural aspects. In order to show the importance and usefulness of this concept, we will base our discussion on a well-known topic in cognitive linguistics: polysemy in perception verbs (Ibarretxe-Antuñano 1999 a,b, 2006, 2008; Sweetser 1999). Both topics are largely discussed in the linguistics literature, and both topics are always problematic. There are different views on what polysemy is (see Cruse 2004; Nerlich et al. 2003), but in cognitive linguistics it generally refers to those elements (either lexical items or constructions) that have different but conceptually related meanings. The starting point is very simple, let's have a look at the following example:

(1) *Peter didn't see what was going to happen if he cancelled the meeting*

The verb *see*, as perception verbs in general, covers a wide rage of meanings apart from the physical sense "perceive by the eyes". The semantic extension "to know" as exemplified in (1) is one of them. The next step is to ask why the verb see can express this meaning, but other perception verbs as in (2) cannot:

(2) *Peter didn't *touch / *taste / smell / hear was going to happen if he cancelled the meeting*

The verbs *touch* and *taste* do no seem to make sense in this context and the verbs *smell* and *hear* are fine, but they refer to different meanings. *Smell* could be paraphrased as "to suspect" and *hear* as "to perceive by the ear" or "to be told". But, why?

From a cognitive linguistics perspective, the link between seeing and understanding is not whimsical or random, but motivated in our own experience. In the case of perception verbs, we have to find this motivation in the physiology of the senses, i.e. the scientific theories that explain perceptual processes, as well as in the psychology of the senses, i.e. the folk theories that people have about how the senses work. This dual perspective is necessary since both sources do not always coincide. The way we think we perceive with the senses sometimes does not correspond to the way in which the physiological processes take place. A clear example can be seen in the traditional classification of vision and hearing as "distant" senses, i.e., perceiver

and object of perception can be far away from each other, in opposition to touch and taste as "close" ones, i.e., perceiver and object of perception have to be close and/or in contact (Sekuler and Blake 1994). In reality, this dichotomy is not physiologically supported; the physical stimulus for vision–light– must penetrate the eyes to be transformed into neural elements. Therefore, vision should also be considered a "close" sense.

But let's go back to our original question: why *see* is related to understanding but not other sense modalities. Perception is a biological process wherein the brain derives descriptions of objects and events in the world[3]. The five sense modalities are our "tools" to help us gathering the necessary information to perceive, therefore, it is only natural that perception is linked to cognition. However, the information we receive from each sense is different, and consequently, different cognitive processes are associated with different senses.

Vision is supposed to be the sense that provides the most reliable and accurate information of all, and this is reflected in the meaning of *see* as "to know" in example (1). There are biological and anthropological reasons that explain why vision is so crucial for us. The centre/surround organisation of the receptive fields of the retinal glanglion cells allows us to detect differences in light level of contrast; our eyes can be orientated towards the object of perception and the optic tracts projected to the lateral geniculate nucleus guide these orienting movements; thanks to the colliculus our eyes can detect objects away from the point of fixation. The result is that vision provides us with the most complete and accurate information about shape, size, orientation, colour, distance and motion of the object. Vision is also considered the most reliable source of information. This belief finds its origin in the Enlightment. Philosophers such as Descartes or Locke saw in the apparently lack of contact between the eyes and the perceived object the basis for the objectivity of vision, and hence, the basis for the scientific value of this sense.

The other senses do not have the same properties. The stimulus for touch, for instance, consists of mechanical disturbances of the skin when in contact with a different object. These mechanical disturbances, even the smallest ones, are registered by several different kinds of specialised "mechanoreceptors" situated in various layers of

[3]For more detailed information about this discussion, see Classen 1993; Howard Hughes Medical Institute 1995; Howes 2003, 2005; Ibarretxe-Antuñano 1999a; Rouby et al. 2002; Sekùler y Blake 1994, among others

the skin. Touch is a source of rich information about the temperature, shape, size, and surface of the object of perception, but we have to bear in mind two things: tactile perception is always superficial and requires contact, or at least, closeness to the object of perception. These characteristics make this sense to be regarded as highly subjective, and therefore, not very reliable.

Smell, on the other hand, is classified as a distant sense, but it is not considered an accurate source of information. The human nose is very sensitive. It is capable of detecting odours as faint as ethyl mercaptan in concentrations as minute as 1 part per 50 billion parts of air (Sekuler and Blake 1994, 426). However, despite this ability to detect odours, the identification and naming of the odour itself is difficult, we know that we smell something but we are not able to identify the smell immediately. This difficulty is termed the "tip of the nose" phenomenon by some researchers (Lawless and Engen 1977).

These differences in the characterisation of tactile and olfactory modalities with respect to sight might shed some light on why the verbs *touch* and *smell* do not develop the meaning "to know", but semantic extensions such as "to affect" and "to suspect, to sense", respectively.

However, bodily experience is not always enough to explain why a specific verb such as *see* in our example develops the semantic extension "to know". There are other factors, such as cultural grounding, that influence and motivate semantic extensions (Ibarretxe-Antuñano 2008; Kövecses 2006). Although it is true that vision is related to cognition in many languages, this does not necessarily mean that this connection works in all languages. Authors such as Evans and Wilkins (2000), for example, have pointed out that in Australian aboriginal languages verbs of hearing are those that establish links with the domain of intellection, whereas the great majority of semantic extensions derived from sight verbs are more related to desire, sexual attraction, supervision and aggression. The relationship between hearing and intellection is also found in the Sedang Moi from Indochina who conceptualise the ear as the seat of reason (Devereux 1991), in Papuan Ommura (Mayer 1982), the Desana of the equatorial rain forest of Colombian Northwest Amazon (Reichel-Dolmatoff 1981), and in the Suya Indians of Brazil (Seeger 1975). Hearing is not the only alternative to vision, other perceptual modalities are also known to be related to this domain. The Tzotzil of Mexico, for instance, consider heat (hence, touch) to be the basic force of the cosmos (see Classen 1993),

and the Ongee of the Andaman Islands in the South Pacific order their lives by smells (see Classen, Howes and Synnott 1994; Pandya 1993). Furthermore, there are cultures in which several perceptual modalities work together in the conceptualisation of cognition. The Shipibo-Conibo Indians from Peru are reported to use visual, auditory and olfactory perceptions to form a body of shamanic cognition (see Gebhart-Sayer 1985).

In this first example, we have used physiological, psychological, and anthropological information to support the idea that language is motivated by our experience and entrenched in culture. In the following section, we will use another source of evidence: psycholinguistic experiments.

2.2 Cognitive Linguistics and Psycholinguistics

Cognitive Linguistics, as we mentioned previously, seeks explanations of linguistic phenomena that help relate language to other cognitive abilities. One very clear example in which the mechanisms postulated by Cognitive Linguistics go well beyond language is Cognitive Metaphor Theory (henceforth, CMT). As has been suggested in section 1.1, *metaphor* and *metonymy* are not just rethorical devices, "linguistic flourishes", so to speak, but actually mental mechanisms that provide powerful explanations for the way in which our whole conceptual systems are structured. Thus, *metaphor* provides a powerful *grounding* mechanism; in a way, we could say that metaphorical mapping is the way in which embodiment is spread throughout our conceptual system. Thus, CMT provides an explanation to the riddle of how we can think about things that we do not perceive directly, intangible notions such as love, friendship, importance, peace, justice or inflation. Basically, what CMT states is that abstract concepts such as these are based on more concrete, embodied domains, of which we do have direct and grounded experience. Information from concrete domains is projected onto the abstract ones, so that the latter are understood more easily and their mental processing is accordingly facilitated. Most of the evidence for the existence of these cross-domain mappings has been taken from language; however, the basic idea behind this proposal is that this is a *mental* mechanism, not merely a linguistic one. It is thus highly relevant not just for linguists, but for all cognitive scientists.

Some cognitive scientists have started to respond to the challenge. Research in this area is a nice example of how the collaboration between cognitive linguistics and other cognitive sciences such as cognitive psychology or social psychology, can be fruitful and mutually beneficial. Linguists, in particular, need to resort to some type of work in these areas before the psychological existence of these constructs can be affirmed. Linguistic evidence has been accused of "circularity or reasoning" (Murphy 1996, 1997; Valenzuela and Soriano 2005), i.e., using linguistic evidence both to postulate the existence of a given metaphor and to prove its existence as well. For example, linguists will notice the abundance of expressions that make reference to "time" using it as if it were money: we say that we *spend* time but also *save, invest, give, rob* or *waste* it. So, on the basis of these wealth of linguistic expressions, theorists postulate the existence of a conceptual metaphor *"time is money"*. And how can we be sure that this metaphor really exists at a conceptual level and plays a role in the cognitive structuring of the domain of TIME in the minds of speakers? Well, just look at how many expressions there are! Obviously, this argument is circular, and collaboration with researchers working in experimental work is therefore basic.

2.2.1 From Cognitive Linguistics to Psychology: Psycholinguistic Evidence on the Existence of Conceptual Metaphors

There have been a number of studies that have seeked and found evidence that cognitive metaphors do have an existence beyond language. The following is a short review of some studies from the fields of cognitive psychology and of social psychology.

BRIGHT IS GOOD/DARK IS BAD. Meier, Robinson and Clore (2004) studied the connection between these two domains by presenting subjects with positive or negative words in a screen, in either dark or bright font. When asked to judge the valence of the words, participants were quicker in the cases in which positive words were presented in bright font and negative words in dark font, and slower in the inverse cases.

HAPPY IS UP/GOOD IS UP. Meier and Robinson (2004) also tested the relationship between what they termed "affect" (a term that included notions such as "happy/sad" and also "good/bad") and "verticality". In their experiment, subjects were quicker to respond to "affective" words, i.e., words with positive valence, (e.g., *hero* or *good*) appearing at the top of the screen than in metaphor-incongruent positions (i.e., at the bottom).

CONTROL/POWER IS UP. Schubert (2005) and Valenzuela and Soriano (2009) have conducted studies dealing with this metaphor. For example, Valenzuela and Soriano (2009) presented subjects with vertically arranged pairs of words. The task of the subjects was to decide whether both items were semantically related or not. The presentation of the stimuli could be either metaphor-congruent (e.g., *captain* above *soldier*) or the other way round. Subjects were quicker to respond in metaphor-congruent positions than in metaphor-incongruent cases.

IMPORTANT IS BIG. Another group of metaphors relate the physical domain of SIZE with different abstract domains. This is what can be seen in the IMPORTANT IS BIG metaphor investigated by Schubert (in press) and Valenzuela and Soriano (2008). Valenzuela and Soriano (2008) reported on a series of experiments in which subjects had to decide which of two factors they judged as more important in their lifes. These "life factors" were abstract concepts and the answer to the task was a matter of personal choice (i.e., there was no "correct" answer). Thus, they would see "friendship" and "money" side by side, and they would have to choose one of these factors as more important for their lives. Size was manipulated by varying the font in which the words were presented; one of them was bigger (20 pt. font) and the other one smaller (12 pt. font). Their results showed that people were faster in their choice of the more important factor when the size was metaphor-coherent (i.e., big in size) than in the inverse case; the opposite tendency was seen when subjects were asked to choose the *less* important factor. In another experiment, Valenzuela and Soriano (2008) used an Implicit Association Test (IAT), in which subjects have to create a novel-compound category made up of compatible or incompatible notions. In the case of the IMPORTANT IS BIG metaphor, subjects were much quicker and accurate when they had to group together "important" words along with "big" words (and "small" and "unimportant" words) than in the non-congruent cases (i.e., associating "important" and "small" words and "unimportant" and "big" words).

TIME IS SPACE. This is the metaphor that has been most frequenty studied by psychologists (e.g., Boroditsky 2000, 2008; Boroditsky and Ramscar 2002; Casasanto and Boroditsky 2008; Nuñez and Sweetser, 2006). There is now abundant evidence that time is construed spatially in a number of languages, though the spatial axis that is used varies from culture to culture; the time line may correspond

to a sagittal axis (front-back) or a vertical one (up-down). Thus, in Western cultures, the future is located in front of us and the past behind us (and we *face* the future and look *back* in anger), while in languages such as Mandarin, the past can be also located "up" and the future "down" (Boroditsky 2001). Additionally, a new type of time line, *with no reflection on language* has been discovered; this will be one of the topics of next section

2.2.2 From Psycholinguistic Experiments to Cognitive Linguistics: Conflicting Results as Suggestions to Improve CMT

In the standard scientific method, theoretical hypotheses have to be confirmed or validated by observation, quite frequently in the form of experiments and from the results of these experiments, additions, rejections or refinements to different parts of the theory are gathered. With the collaborative efforts between different cognitive scientists, cognitive linguistics has also entered this cumulative cycle. Now, there are psycholinguistic experiments which are providing data which could not possibly be gathered from linguistic studies, and that can prove extremely useful in refining CMT. We will review two examples of this case.

LEFT-RIGHT MAPPING OF TIME. There are now quite a few studies on the spatial representation of time that demonstrate that time is mapped not only on front-back or up-down axes, but on a left-right horizontal axis (Fuhrman and Boroditsky 2007; Santiago, Lupiáñez, Pérez, and Funes 2007; Santiago, Román, Ouellet, Rodríguez, and Pérez-Azor 2008; Torralbo, Santiago, and Lupiáñez 2006; Tversky, Kugelmass, and Winter 1991). This is specially interesting because this specific metaphor has been mentioned as absent from all human languages (Haspelmath 1997; Radden 2004), the only exception being signed languages (Emmorey 2001). For example, Santiago and collaborators have a number of studies in which subjects are presented with Spanish words making reference to time (either tensed verbs or adverbs), and found that words referring to the past are processed more quickly when they appear on the left side of the screen while future words are processed more quickly when appearing on the right side. Another valuable contribution of this research group concerns the flexibility in choosing one or another metaphor for time; Torralbo et al. (2006) were able to uncover how we choose between left-right or front-back metaphors. Participants were asked to judge if a word appearing to the front or the back of a side-looking head

silhouette referred to the past or to the future, and to supply their answer orally. In this experiment, participants were faster to respond when past words were presented to the back of the head and future words were presented to the front, in concordance with the front-back metaphor of time. However, in a different experiment, participants were asked to give a left-right manual response (by pressing a key). This time, the type of answer activated a left-past right-future representation of time, which overruled the front-back mapping (and thus, past words presented on the left were answered more quickly, and future words on the right, regardless of the direction of the silhouette, that is, disregarding front-back information).

SIMILARITY IS CLOSENESS. Casasanto (2009) studied this metaphor by performing a number of experiments. In the first one, participants were asked to rate the similarity of pairs of abstract words (e.g., *grief* and *justice*) which appeared side by side in the screen, but located at three different distances (close to each other, separated from each other, or far from each other). In this experiment, participants tended to judge the same word-pairs as more similar when they appeared close to each other than in the more distant positions, which is in concordance with the mappings proposed by the metaphor (and is reflected in the patterns found in language, e.g., *that's not the correct answer, but it's close*). However, in a second experiment, he used unfamiliar faces as stimuli, and the inverse effect was observed: the closer they were, the less similar they were judged and vice versa, something that contradicts the predictions of CMT. In a final experiment, he asked participants to rate the similarity of concrete objects by using one of two criteria: either perceptual similarity, or function (use). Participants who used the criterion of function to rate the similarity tended to lump together similarity and physical proximity (in concordance with the linguistic metaphor); the same objects rated by participants who were told to rate their perceptual similarity exhibited the same inverse relationship observed with faces: the closer, the more dissimilar they were judged. So, it would seem that when judging literal formal similarity, the metaphor SIMILARITY IS CLOSENESS does not play a major role (maybe overridden by other factors like ease of perception–and therefore ease of comparison–in items that are close by), while it is activated in a more abstract assessment of similarities between two elements (beyond their physical appearance).

These two examples show how a better understanding of how conceptual metaphors work can be achieved by taking into account experimental results coming from other cognitive sciences.

2.3 Cognitive Linguistics and Robotics

One innovative line of work in which the relationship of cognitive linguistics with other cognitive sciences is especially manifest is the interaction of robotics and cognitive linguistics. Work by Steels (Steels 1997a, 2002, 2003, 2008) has approached the investigation of the emergence and evolution of linguistic structures by means of linguistic experiments with "embodied autonomous agents" (i.e., robots). In this line of research, language is seen as a "dynamic complex adaptive system", able to self-organize and evolve as the communicative needs of users so require it. Self-organisation is a phenomenon in which increasingly complex structures are formed without guidance of any outside source or central controller; such is the case of the formations of termite nests or of paths in ant colonies. Different phenomena in various scientific disciplines have been most successfully described in this way, such as crystalization in physics or protein folding in chemistry/molecular biology. Language can also be seen as a clear example of a dynamic complex system which is shared by a speech community without central control.

More specifically, the overall goal in this approach is to try to arrive at a detailed model of how artificial communication systems emerge, how they are invented and negotiated among the agents, and how they evolve adapting themselves to the communicative needs of speakers. The basic paradigm used is the "language game". A real-world example of a language game would be a speaker who addresses a hearer by asking the question *Can you pass me the salt, please?* In this case, the language game would be considered a success if the hearer passes the salt (or if s/he shows in any other way that s/he has understood the message). In a robotic context, language games can be defined as "routinized local interactions" (or "scripts"), embedded in a real-world situation and with a concrete communicative goal. The games always start with a population of robots who are able to build their own grounded sensorimotor representation of the world and are endowed with certain cognitive capacities (e.g., learning capacities). The robots have to solve a given communicative problem; successive interactions between pairs of robots (randomly chosen to ask as speaker or hearer) allow the population of agents to explore alternatives, until a final conclusion is (hopefully) reached by means of group dynamics.

One initial example: Steels (1997a) used self-organization to investigate the formation of coordinated vocabularies. In one of the experiments, agents have to learn to communicate to each other a set of predefined meanings. If the speaker has no word for a given meaning, s/he will invent a new one; this new word might be adopted by the hearer and used in a next interaction with another agent. When agents use a form-meaning mapping that leads to communicative success, this mapping is rewarded by increasing its "success score"; conversely, other alternative mappings known by the agent (that is, other words that could express the same meaning) are "punished" (a mechanism similar to "lateral inhibition" in neural systems). In this way, out of the many hypotheses that are initially proposed by the different members of the robotic population, a more reduced set is chosen that everybody tends to use. In this way, after a number of rounds of negotiation, a shared set of form-meaning mappings emerges without the need for central control.

This paradigm has been applied not just to the formation of vocabularies, but to the formation of ontologies: Steels (1997b) addressed the simultaneous formation of conceptual spaces and linguistic vocabulary. This time, agents did not start from a set of predefined meanings. They played a "guessing game": the speaker had to choose one of the objects in the context and try to draw the hearer's attention to it by saying a word. The game is considered a success if the hearer points with his arm to the correct object; if the game fails and the hearer points to some other object, the speaker will point to the intended one. In this game, the communicative demands of the task chosen are the driving force. So, when the speaker selects one of the objects of the context to talk about, s/he is compelled to "conceptualise a meaning" which discriminates it from the other objects in the context. That is, the speaker will have to examine her representation of the world and will have to decide a possible minimal set of features that can discriminate the topic from the other objects in the context. For example, in the case in which the topic to be communicated is a red ball and there are also three yellow balls present in the context, then the colour of the topic could be a good discriminating feature. The agent will then invent a new word for this "concept" or meaning, and will communicate the word to the hearer. Of course, especially in the initial stages of the game, the hearer will then face a communicative problem: the word used by the speaker will quite probably be unknown to the hearer. If this is the case, the game will

fail; however, the interaction finishes when the speaker points to the intended object. Upon seeing this, the hearer will try to guess the intended meaning of the word used (perhaps, round things? Or red things?) through the same discrimination game used by the speaker before uttering the word, that is, the hearer will try to come up with a minimal set of features that distinguish the intended object from the rest, that could be taken as a good guess of the meaning of the word. It is true that there may be many different sets of discriminating features possible in a given case (the *gavagai* problem), but as the agents play a sufficient amount of language games, once they reach an agreement on what form-meaning pairs there are in their language, the conceptual space associated to each word can also be said to have been reached. This type of experiments has been successfully applied to other domains, such as colour terms (Steels and Belpaeme 2005) or spatial language (Steels and Loetzsch 2008).

Van Trijp (2008) is another example of how this paradigm can be used to investigate the formation of more complex grammatical structures, namely, case grammars and its associated semantic roles. Van Trijp starts from the hypothesis that grammars emerge and evolve in order to allow language users (1) optimise their communicative success and expressiveness, and (2) reduce the cognitive effort that is needed for the semantic interpretation of utterances. In his experiments, artificial agents engage in a series of language games in which the speaker has to describe a dynamic event to the hearer: there is a scene with two participants (two puppets) who carry out a number of actions, such as walking, or pushing blocks to each other. The overall goal this time is to find out which communicative pressures and which cognitive mechanisms are minimally required that will bring about the automatic formation of a shared case grammar. As previously, communicative pressures are embedded in the requirements of the language game to be played. In this case, agents play a "description game": the speaker has to describe an event that both agents have seen, and the game succeeds if the hearer agrees with the description offered by the speaker. Additionally, the agents are endowed with certain "cognitive mechanisms", which are thought to be necessary for the formation of the grammatical system: there is a *diagnostic system* that allows the agent to detect communicative problems (e.g., the robots can be aware that their available grammatical repertoire does not allow them to express one given event in an unambiguous way), there are *repair strategies* for solving these problems (e.g., the

robots can then decide to invent a new grammatical device to solve the problem, and thus enrich their grammar with a new grammatical marker to indicate who is the "agent" of the interaction, for example), and finally, *alignment strategies*, that will allow the coordination of their linguistic inventories with other members of the population (again, by the use of lateral inhibition). All linguistic information is stored in the form of "constructions", which are updated after each linguistic exchange. Finally, an "ecology" of constructions is formed, showing how grammatical constructions for marking event structure significantly optimise communication by reduce ambiguity, and decrease the cognitive effort needed for interpretation.

For this and other works, this research team has created a computational version of Construction Grammar, called *Fluid Construction Grammar*. The "fluidity" of this version comes from the "fluid" nature of grammar, which is continuously transformed and updated by the usage-events of speakers. Construction Grammar is considered as specially suitable theory for these experiments, for a number of reasons: its use of the notion of construction itself (with its pairings of form and meaning), its ability to ground linguistic structures in the real world by linking them to embodied sensori-motor experiences, and its "usage-based" character, which sees grammar as emerging from actual communicative usage-events, and negotiated among the members of a linguistic community. Needless to say, the benefits that these experiments offer for Construction Grammar and, for Cognitive Linguistics in general, are potentially many; in this sense, it is enough to mention the advantages that modelling in general offers any (cognitive) science, as McClelland (2009) forcefully argues.

Finally, and regardless of the problems which are still remaining and of all aspects that have to be further investigated, this paradigm has shown its effectiveness in investigating language emergence and evolution, and has greatly contributed to solve the Symbol Grounding problem (Harnad 1990), ever present in all the "classic" approaches to cognition:

> "I argue that these experiments show that we have an effective solution to the symbol grounding problem, if there is ever going to be one: we have identified the right mechanisms and interaction patterns so that the agents autonomously generate meaning, autonomously ground meaning in the world through a sensori-motor embodiment and perceptually grounded categorization methods, and autonomously introduce and negotiate symbols for invoking these meanings. The objective test for this claim is in the increased success of agents in the language games" (Steels 2008, 239)

3 Conclusions: Future Paths

The description of language as a dynamical complex system is not assumed in an explicit "combative" fashion in CL. However, most of the tenets of CL are in fact completely compatible with such a view of cognition. It is also true that, to some, certain assumptions or current practices of CL could seem to be in a certain degree of contradiction with this line of thought. For example, against the trend favoured by dynamic complex explanations of cognition of distressing the role of internal representations, that is, of offloading content onto the interaction between brain, body and world, CL seems to be still looking mainly at the internal brain/mind structures that explain phenomena, and thus it could fall prey of the criticisms of "mainstream cognitivism", of providing explanations which are too powerful and can be more simply and rightfully explained by looking at mechanisms existing in the world, such as has been the case in explanations of many facets of children development, from learning to walk to perseverative reaching (a.k.a., as the A-not-B error)(Port & Van Gelder 1995; Thelen & Smith 1997; Van Geert 2000; Smith & Thelen 2003).

However, the current emphasis in CL in elucidating mechanisms by looking at brain-internal explanations is just a historical reaction, and is still completely necessary. And, in fact, as we have said, if one looks at them from this new perspective, many of the tenets and approaches of CL can be considered as completely compatible with a dynamical system approach to cognition. For example, the notion of "emergence", which is a key notion in these approaches, figures prominently in CL. Thus, what CL considers as the main unit of language, the construction, is seen as emerging from cognitive, functional and discourse pressures, and thus, not just based on internal-cognitive mechanisms, but from the interaction of different ecological sources, a stance that would satisfy even the staunchest supporters of dynamic system theory. And indeed, we saw how this could work in section 2.3., when we described the robotic learning of constructions. The same could be said for the conception of "meaning" itself, which

again is seen as emergent from various activation sources, discourse functionalities, and constrained by a number of construal biases.

Even more "representation-based" notions in CL, such as metaphors or blends, can be easily given an explanation which fits the dynamical view. For example, this is what the cognitive psycholinguist Ray Gibbs expressed in an interview with Javier Valenzuela, published in *Annual Review of Cognitive Linguistics* (2009):

> "Cognition emerges from the continuous interaction of brains, bodies, and world, and always retains its connections to ongoing embodied activity [...] Image schemas and primary metaphors are not internal, mental representations that are abstracted away from experience, but retain their sensorimotor connections/motivations given people's ongoing embodied experiences in the world [...] we should not simply view constructs, such as image schemas and conceptual metaphors, as representational entities inside people's heads, but as contextually-sensitive emerging products given brain, body, and world dynamical interactions. Different cultural, linguistic, and cognitive forces dynamically interact to constrain the emergence of metaphoric thought and language in context"

Thus, with its emphasis on the interaction of linguistic abilities with other cognitive abilities, and its broad perspective that sees language as emerging from socio-physical embodied experiences, Cognitive Linguistics can rightfully be considered as an approach completely compatible with complex dynamic system theories of cognition, which opens new venues of collaboration that will no doubt enrich both approaches. Both approaches also offer each other exciting challenges: on the one hand, dynamic system theory has mainly focused on low-level phenomena, while higher level cognitive mechanisms have not figured that prominently in this type of explanations; on the other hand, it remains to be seen how the application of the methodological tools of dynamic theory (with its advanced use of mathematical tools such as differential equation modelling) could be applied to the description of linguistic phenomena[4]. In any case, it is clear that the future interaction between these two disciplines will help us to achieve richer and more detailed theories about cognition and language.

[4]Though there have been some initial attempts; in this respect, see Petitot (1995).

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Chapter Two

Grammatical Inference and Natural Language Acquisition

Leonor Becerra-Bonache

1 Introduction

Despite the complexity of natural languages, children are able to learn any natural language given the adequate input, and they do so effortlessly, without any specific training, with a limited exposure to data and in a short amount of time. However, the ease with which children acquire their native language contrasts with the difficulty to explain this process.

The understanding of the human ability to acquire their native language has motivated a big amount of research. However, in spite of all research efforts in different areas, the human learning mechanisms that underlie first language acquisition are poorly understood. The desire to better understand natural language acquisition has motivated research in formal models of language learning. As Parekh and Honavar pointed out, by studying formal models of language acquisition, several key questions on natural language can be answered:

> *The issues and practical difficulties associated with formal language learning models can provide useful insights for the development of language understanding systems.*