Embodied semantic parameters for the lexical representation of spatial relational categories

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This paper proposes an explanatory model for the lexical representation of the native speakers' lexical knowledge of English prepositions. Lexical knowledge of prepositions as relational predicates includes argument structure (trajector-landmark) as in *Cognitive Grammar*, situation types (position vs state) as in *Functional Grammar*, lexical hierarchies (spatial subdomains) based on semantic primitives, as in *Natural Semantic Metalanguage*, and embodied perceptual parameters configured in four dimensions, namely, geometry, topology, force-dynamics and function (from *Cognitive Linguistics*). This model is illustrated here by expounding three lexical templates compatible with constructional templates in the *Lexical Constructional Model*, representing the semantic decomposition of English prepositions *at*, *on* and *in*.

Keywords: embodiment, lexical knowledge, lexical representation, prepositions, semantic decomposition

1. Introduction

This paper goes about lexical knowledge, that is, the knowledge humans, as naïve speakers, have about the meanings of the words they use. More concretely, it explores how a theory of language can represent embodied lexical knowledge in a reasonably formalised system. Recent lexical functional models like the theory of the *Generative Lexicon* (James Pustejovsky 1995), *Role and Reference Grammar* (Robert D. Van Valin, Jr. 2005), or the *Lexical Constructional Model* (henceforth LCM) (Ricardo Mairal & Francisco José Ruiz de Mendoza Ibáñez 2008, 2009) posit different levels of representation for various types of lexical information. Thus, Argument Structure shows the information on the functionality of elements, Event Structure represents information related to event types,

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Inheritance Structure represents relations between a lexical item and others in the lexicon, and Perceptual Structure defines attributes of an object or a relationship. In this paper, we address issues concerning the lexical templates (henceforth LTs) representing this type of lexical knowledge and their internal constraints. The theories mentioned above have mainly dealt with representing lexical knowledge of verbs. Here, however, the focus lies on the representation of a closed set of lexical items such as prepositions – or spatial particles – assuming that all the semantic components described are considered to emerge from embodiment on the grounds of experiential language acquisition and learning.

Spatial relational categories manifest as a type of linguistic expression to represent and conceptualise the visual dimension, i.e., what we can see (Jordan Zlatev 2007; Peter Gärdenfors 2015; Kurt Stocker 2015). In other words, spatial language expresses how we conceptually organise things and phenomena relative to each other in space. In linguistics, this type of relation is called spatial relation. The class of words or set of lexical items representing that kind of relation in English are, prototypically, the set of prepositions. So, English prepositions represent, express or symbolise spatial relations and therefore constitute one of the most relevant parts of spatial language. For a proper understanding of spatial semantics, it is crucial to grasp the notion of "spatial language" (see Zlatev 2007), i.e., what literal meanings in spatial language consist of and what cognitive mechanisms allow us to figure out how those literal meanings are mapped or transferred onto figurative domains (for metaphorical uses see Frank Boers 1996; Antonio José Silvestre López 2009; Brooke O. Breaux 2013; Anja Jamrozik & Dedre Gentner 2015; Marlene Johansson Falck & Lacey Okonski 2023; among others).

Traditionally, prepositions were treated as empty words without lexical meaning (e.g., Viggo Brøndal 1948), and consequently, their figurative uses were considered chaotic and unmotivated for a long time. Likewise, concerning literal spatial meaning, prepositions were considered meaningless until the emergence of Cognitive Semantics in the second half of the twentieth century. Traditional and structuralist linguistics claimed that the figurative senses of prepositions could not be accounted for because no relation could be established between physical space and figurative language. Even nowadays, at the first stages of foreign language learning, teachers still repeat once and again that there is no motivation for particular uses of prepositions in most contexts, and learners acquire them just by listening to and imitating native speakers.

During most of the twentieth century, linguists focused on the functional character of prepositions in Grammar (Randolph Quirk et al. 1985). This class of words was regarded as a set of relational, functional elements, either morphologically or syntactically, and defined as pure relators (Brøndal 1950; Bernard

Pottier 1962), case government markers (Louis Hjelmslev 1935; Charles J. Fillmore 1968), third rank complements (Otto Jespersen 1924), or categorial *traslators* (Lucièn Tésnière 1959). Some authors suggested prepositions might be considered a lexical category, although no semantic descriptions resulted from these proposals (e.g., Noam Chomsky 1993; Ray Jackendoff 1983; Manfred Bierwisch 1988). Recent functional models fail to provide detailed semantic characterisations beyond general spatial notions. Thus, early versions of *Role and Reference Grammar* use broad labels like Locative, Place (LOC-Place) and Path (LOC-via) to describe the whole set of prepositional meanings (Julia Jolly 1991). Even *Construction Grammar* does not go beyond broad denominations such as PATH or MOTION (Adele E. Goldberg 1995). In contrast, during the last decades of the twentieth century and beyond, a considerable body of research has investigated what prepositions mean, literally and figuratively, within the context of *Cognitive Semantics* (Sally Rice 1992, 1996; Chris Sinha & Lis A. Thornseng 1995; Andrea Tyler & Vyvyan Evans 2003; Seongha Rhee 2004; Seth Lindstromberg 2010; Paul Chilton 2014; George Takahashi 2016; and many others; see also Section 2).

Drawing on the *Cognitive Semantics* tradition, this paper aims to show the lexical character of spatial relational units whose meaning can be described and explained through semantic parameters beyond descriptive lists of contexts or collocations (Karl-Gunnar Lindkvist 1950, 1976) by superseding the Euclidian approach based on geometric axes – vertical and horizontal – and dimensions -points, lines, surfaces and volumes (David C. Bennett 1975; Geoffrey N. Leech 1969). The purpose is to expose the lexical-semantic structure of prepositions from the perspective of embodied meaning as has been developed in the *Cognitive Linguistics* paradigm (e.g., Leonard Talmy 2003) and propose a formalism encompassing these semantic parameters with the lexical templates used in the *Lexical-Constructional Model* (Mairal & Pamela Faber 2007). Thus, this work expounds on the cognitive and perceptual parameters for the linguistic comprehension of spatial relationships and their linguistic expression in the lexical category of prepositions. The ultimate aim of the paper is not to present new data on prepositional meaning but rather to organise the lexical knowledge of prepositions as a lexical class into a formalism (a Lexical Template for the category) compatible with lexical and constructional templates within the framework of the *Lexical-Constructional Model*. For that purpose, the paper draws on the lexical knowledge of prepositions built by *Cognitive Linguistics* in recent decades.

2. From Euclidean geometry to embodied accounts of prepositional meaning

The Euclidean approach (Bennett 1975; René Dirven 1989) describes spatial relationship meanings based on classical Euclidean geometry. The tools employed are two geometric axes, vertical and horizontal, and the three spatial dimensions defining lines, surfaces, areas and volumes. In this approach, the uses of a preposition are reduced to a *core sense* introduced in the lexicon. In turn, the context provides other aspects of meaning that do not belong to the preposition. This approach postulates that there is only one sense for each preposition in various contexts. These contexts introduce nuances of meaning that can be assigned to the preposition, but the *core sense* is present in all of them. Annette Herskovits (1985, 1986) named that core sense "ideal meaning" and described a set of "use types" that showed conventional derivations from those ideal geometric meanings under the effect of pragmatic principles and the speakers' world knowledge. Independently of the accuracy and exhaustiveness of Herskovits' set of "use types", the importance of her contribution resides in her noticing additional factors beyond geometry that prompt a variety of uses or senses. She posed saliency, relevance, tolerance and typicality as pragmatic principles that may lead speakers to shifts in prepositional usage. As a theoretical consequence, later work on the polysemy of prepositions looked beyond geometry to discover additional parameters in the speakers' lexical knowledge of prepositions to be incorporated into semantic descriptions. The focus turned to the mental representation of spatial relations rather than space itself. The issue is whether those mental representations are embodied or disembodied. We endorse the embodied option, and in the following, we offer some arguments favouring this position.

Some fundamental arguments for embodied linguistic meaning are provided by the causal theory of perception (John Locke 1690), the phenomenology of perception (Maurice Merleau-Ponty 1945) and the theory of enactive meaning (Francisco J. Varela et al. 2016).

Locke's (1690) causal theory of perception asserts that in optimal circumstances of actual true perception, it is nonsense to identify its content and the elements of that content with present actual conditions in the external situation that correspond to it. According to Locke, perception is a private individual experience in the sense that two people cannot have the same perception, but rather each has a personal experience of it. Secondly, perception is transparent so that it is felt by someone, i.e., occurs in a human body. Thirdly, perception is irreducible since it cannot be scientifically described to be better known than through the mere fact of experiencing it. Finally, it is nonsense to speak of the correctness or incorrectness of perceptions because they just occur uniquely in every

human being. Locke's view buttresses the notion of language use and knowledge in a cognitivist, experientialist approach. Hence, language cannot directly refer to non-mental entities because we do not have direct access to the external world. In addition, the extralinguistic reality is not the primary meaning of words but is linked indirectly to words by ideas, these being the content of experience. Thus, the meanings of prepositions do not refer to real-world, objectivist, spatial relationships between entities but to spatial relationships as conceptualised by human beings.

The embodiment hypothesis in linguistics also draws from Merleau Ponty's (1945) phenomenology of perception, where natural language is not an instrument or a means but a pure manifestation of human nature, psychically networked to the world and our peers. For the human psyche, perception, (self-)motion, and interaction co-occur as a single phenomenon. Figure 1 illustrates these components of the human experience of space in line with Merleau Ponty's approach to perception.

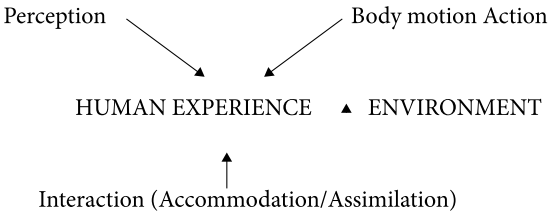


Figure 1. Components of human experience

Figure 1 suggests that the interactive dimension incorporates psychic developmental processes of adaptation to the external world and assimilation of the environment (Jean Piaget & Bärbel Inhelder 1956). Experience consists of an amalgam of sensations and sensory-motor patterns linking the individual with the environment. Paul Douglas Deane (2005) suggests that prepositions incorporate these aspects of experience in their meanings, leading to the multidimensional character of the semantic structure of spatial relations. Thus, a spatial predicate expresses not only the mere location of a trajector (TR) and a landmark (LM) (Ronald W. Langacker 2013) in geometrical space (Terry Regier 1996) but also a configuration (topological perception) with a particular orientation for movement according to force dynamic schemas (Mark Johnson 1987; Talmy 1988) for some purpose or function (Claude Vandeloise 1991, 1994; Kenny R. Coventry & Simon C. Garrod 2004). The latter is an aspect of meaning that emerges due to the interactive character of cognitive development postulated by Lev Vygotsky's theory of social cognition (Vygotsky 1986).

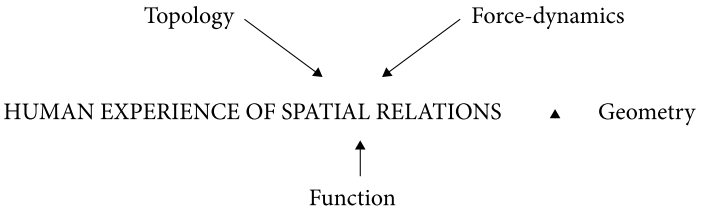


Figure 2. Components of the human experience of spatial relationships

In line with this scheme, an expression like *the postman (is) at the door* represents a conceptualisation where a postman is geometrically located in space in the spatial region relative to a door so that the two participants constitute a topological configuration and are oriented for movement in a particular direction, interactively. Diverse authors like Coventry et al. (1994), Laura A. Carlson-Radvansky et al. (1999), and Coventry & Garrod (2004) have extensively illustrated that the participants' function and purpose significantly influence how the spatial relation expressed by a preposition is applied to a particular spatial configuration in contrast with other prepositions.

In this line, Sinha & Kristine Jensen de López (2000: 21) reformulate the embodiment hypothesis so that "the human body (and nervous system) interacting with the physical (and social) world is the universal source of image schemas (and event schemas, force dynamic and motion schemas)".

Varela et al. (2016) propose enactive cognition and meaning to account for semantic phenomena. For them, "enaction" brings forth a conceptual world consisting of various levels of interconnected sensorimotor networks that become part of the ongoing existing world and shape it. The enactive approach makes two assertions (Varela et al. 2016: 173): "(i) perception consists in perceptually guided action and (ii) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided."

According to this view, spatial relations, as conceptualised by language users, are not "out there" independent of our perceptual and cognitive capacities, but instead, they are experiential, even assuming that our biological and cultural world influences them. That mutual determination defines enactive cognition. An enactive approach will describe spatial meaning by including our embodied experience. The enactive meaning of prepositions incorporates, therefore, semantic parameters for emotion, interaction, purpose, and sensorimotor programmes, in addition to the geometry. The following questions would provide clues for the semantic parameters defining the embodied meanings of prepositions and the relationship between TR and LM:

Where is TR PREPOSITION LM?
How does TR feel PREPOSITION LM?
How does TR move PREPOSITION LM?
How does TR keep its position PREPOSITION LM?
What is the purpose of TR PREPOSITION LM?
What does TR do PREPOSITION LM?

According to this view, the feeling experienced by a human perceptual sensorimotor system should be accounted for as a consistent part of the meanings of spatial relational categories like prepositions.

This hypothesis has been tested in Cognitive Neuroscience. Daniel Casasanto (2022) formulates the *embodied simulation hypothesis*, according to which part of the meaning of a word (or a phrase or a sentence) is a *simulation* of its referent, implemented in neural and cognitive systems that support perception, action, and emotion. World information enters our minds via modality-specific systems (visual, auditory, motor). Modality-specific activity leads to the formation of longer-lasting memory traces stored in non-modality-specific convergence zones in the brain (Lawrence W. Barsalou et al. 2003). According to the *embodied simulation hypothesis*, modality-specific brain areas play essential roles in processing both word meanings and forms so that each word form cues modality-specific simulations in the relevant brain cortices, constituting the word's meaning (somatosensory, motor, and visual). Language users are not aware of these simulations. Casasanto reports some fMRI studies providing evidence that supports the *embodied simulation hypothesis* by showing that modality-specific perceptual and motor areas are selectively activated by language referring to our perceptual and motor experiences. Additionally, MEG experiments show that somatotopic motor simulations are detected within tens of milliseconds after word form identification, which suggests that simulations indeed happen fast enough to construct linguistic meaning as the *embodied simulation hypothesis* posits (see Friedemann Pulvermüller 2005, for a review of relevant MEG studies). Finally, some experiments using TMS (Roel M. Willems et al. 2010) provide evidence that somatotopic motor activity of particular modality-specific brain areas plays a causal role in processing particular meanings, which supports the *embodied simulation hypothesis* (for an updated overview of embodiment in Cognitive Linguistics, see Xu Wen & Canzhong Jiang 2021).

Many studies have approached the embodied nature of prepositional meaning in recent decades (for overviews, see Zlatev 2007; Coventry 2015). Herbert H. Clark (1973) distinguished perceptual space from linguistic space to focus on perception as a source of meaning. Procedural Semantics (George A. Miller & Philip N. Johnson-Laird 1976) posits a semantic judgement on perception so that

speakers' perceptions filter the relation between the world and language. Procedural Semantics claims that a lexical concept has a *definitional part* which consists of a schema for recognising instances plus a *connotative part*, i.e., knowledge associated with that concept, including the relation to other concepts. Thus, spatial relations consist of a perceived topology including two participant entities: a referent (salient and movable) and a relatum (less mobile and salient). Procedural Semantics introduced perceptual parameters like the distinction between absolute vs relativistic space and the notion of the *search domain* as an attentional variable (a precedent to Langacker's *active zone*). Procedural Semantics formalisations reflect the asymmetry of spatial relationships, the relevance of attention and experience in characterising the qualitative difference between the participants and the salience of diverse regions in space perception. Their definition of the preposition *at* illustrates that asymmetry (Miller & Johnson-Laird 1976: 390):

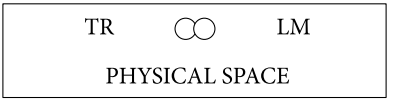
AT(*x*,*y*): A referent *x* is at a relatum *y* if:
i. INCL (*x*, REGION (*y*))
ii. not (INCL (*y*, REGION (*x*))

The embodiment hypothesis for the semantic structure of prepositions incorporates the prototype theory of categorisation and pre-conceptual image schemas by applying the prototype approach from perceptual Psychology to the description of prepositional categories (Claudia Brugman 1980; Susan J. Lindner 1983). Brugman (1980) introduced radial networks to describe sense extensions from a central sense or prototype. Lindner (1983) introduced the notion of image schema to describe spatial relations expressed by the spatial particles 'up' and 'out'.

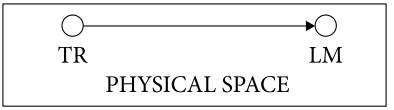
Bruce W. Hawkins (1984) introduced the dynamic dimension to the meaning of prepositions by making distinctions based on the focalisation of attention on diverse parts of a schema. Figure 3 shows the focus on the end of a path schema, in contrast with the absence of a path, to describe particular senses of *at* and *in*.

Alan J. Cienki (1989) described the conceptual structure of prepositions as a set of necessary, centrality and typicality conditions according to four parameters, namely, topological relations -such as contact, coincidence, intersection, boundary or interior-, geometric relations -like point, line or surface-, physical relations -like support or attachment- and metric conditions – proximity, juxtaposition, and distance. Figure 4a and Figure 4b shows the preference options for prepositions *in* and *at*.

As for radial networks, Langacker (1991: 266–272) proposes a taxonomy of node types where each node corresponds to what he calls "established senses". These are all connected by arrows indicating the particular categorising relationship that links each sense to the other. This relationship is one of *specialisation*

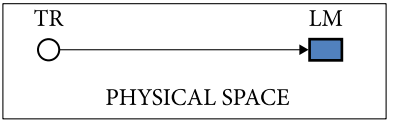


a. He sat at the roll-top desk



b. They poked sticks at him

c. Barry was making a fool of himself in the kitchen



d. I get in that house fast

Figure 3. Image-schematic approach (Hawkins 1984: 377)

In:

[SpE INTERSECT INTERIOR OF L-r (Nec)]
{CLOTHING}
{INSTITUTION}
{FILLED SOLID}
Pref{[Place IN([Thing{CONTAINER} D]}
{[Path TO ( )]}

Figure 4a. Preference options for *in*. (Cienki 1989: 151)

if it "holds between a schema and a structure that elaborates or instantiates the schema" (symbolised by a solid arrow), or it may be a relationship of *extension* if it implies some conflict in specification between the primary and extended values. Thus, the extended value is incompatible with the primary one in some respect but is nevertheless categorised by it (symbolised by a dashed arrow).

One crucial aspect of the embodiment hypothesis is the perceived relative function of the participants in a mental space representing a scene. Vandeloise

At:

SpE COINCIDENT WITH PLACE OF L-r -POINT (Cent)
SpE FUNCTIONALLY ORIENTED TOWARD L-r -OBJECT OF ACTIVITY (Typ) (Cent)
{POINT}
{(BOUNDARY OR CONTAINER)}
Pref {[Place AT ([Thing {(BOUNDARY OR CONTAINER) – OBJECT OF ACTIVITY} D]}
{[Path TO ( )]}

Figure 4b. Preference options for *at* (Cienki 1989: 152)

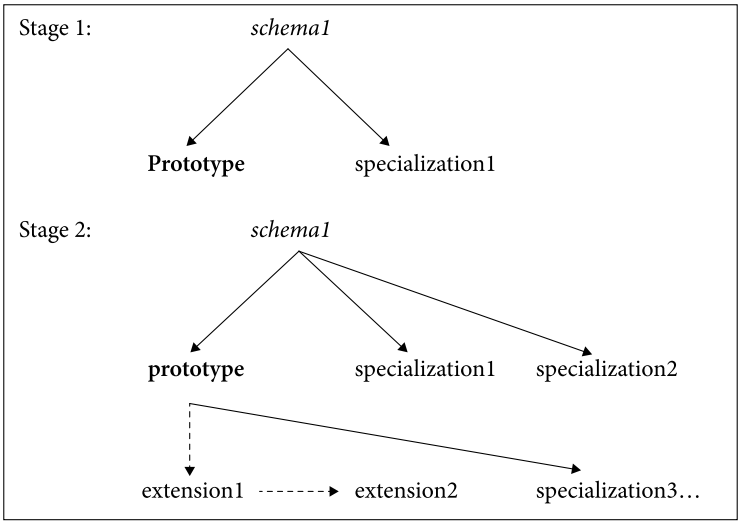


Figure 5. Langacker's network

(1991, 1994) posits the centrality of function to determine what prepositions mean for language users. The crucial aspect of Vandeloise's view is interaction. Thus, to define the French preposition *à*, the position of the TR must be associated with particular routines for interaction (Vandeloise 1991: 157):

"A_1: *x est à y* if *y* localizes *x*"
"A_2: *x est à y* if the positions of *x* are associated in a routine evoked by *y*"

Vandeloise analyses the example "The bulb is in the socket" to illustrate that the relation expressed by "in" refers to the function of the socket concerning the bulb rather than just their relative location. Being of similar size and topological configuration, the bottle and the cap in "*The bottle is in the cap" do not bear an analogue functional relation, which makes this sentence unacceptable. To define this relative function of the participants, Vandeloise proposes the notion

of *complex primitive* as a sort of family resemblance. Thus, for the preposition *in* (i) the contained object moves towards the container, (ii) the container controls the movements and/or prevents access to the content, and (iii) the contained object is included, at least partially, in the container or in the convex closure of its containing part (Vandeloise 1994: 173). Not all the traits in that family resemblance set are necessary for all contexts; just one is sufficient for prepositional use.

The role of function in prepositional semantics has also received primary attention in Psycholinguistics. After Vandeloise, function in prepositional meaning has been investigated along a series of psycholinguistic lines of research. Carlson-Radvansky et al. (1999), Coventry et al. (1994) and Coventry & Garrod (2004), among others, have expounded experimental evidence of the influence of extra-geometric factors as the typical function and the force constraints of the participants.

3. Spatial relations lexical knowledge

How can the embodied lexical knowledge of prepositions in the speakers' minds be expounded or formalised to be processed within a lexical constructional model that posits lexical-constructional subsumption? Beyond RRG, the LCM claims that prepositions are lexical units with embodied meaning that may be analysed within a Cognitive Linguistics framework. Therefore, we need to define the semantic parameters for that lexical representation. Cognitive Grammar (CG) (Langacker 1987, 2008, 2013) has paid attention to the semantics of spatial predicates. CG defines a unit as "a thoroughly mastered structure that a speaker can activate as a preassembled whole without attending to the specifics of its internal composition" (Langacker 2008: 16). Therefore, a unit constitutes a cognitive routine. Lexical units take the form of symbolic units with both a semantic pole and a phonological pole, and nothing else is required. Accordingly, English spatial prepositions as relational expressions represent the speakers' conceptualisation of interconnections among conceived entities. Interconnections are cognitive operations that assess the relative positions of entities within the predication's scope. In the previous section, we reviewed some examples of the extensive tradition in analysing spatial polysemy in the Cognitive Linguistics paradigm. In line with that background, we propose four components to represent the embodied meaning of prepositions and their predications: First, we need to identify the entities in the relationship and their relative constructional function as an argument structure. Second, the situation type depends on the kind of scene that comes about involving the participants (Aktionsart). Third, perceptual parameters determine the qualia structure of the

relationship. Fourth, a lexical inheritance hierarchy is sketched to show the organisation of the prepositional mental lexicon.

3.1 Argument structure

Argument structure includes the participants in the predication as usually expressed by the syntactic components in a construction. We consider prepositions as relational predicates that require two additional concepts to conceptualise a spatial scene. A relationship is conceptually dependent on its participants; it evokes its participants (if only schematically) as an intrinsic aspect of its conception. Consequently, the focal participants in a profiled relationship are part of the relational profile. TR and LM are inherent in the meanings of relational expressions, even when the focused elements fail to be overtly manifested (Langacker 1987, 2008, 2013). These two entities are conceptualised in the same construal event as the relational concept. The TR is the localised or foregrounded entity, construed as the movable element in the relationship. Conversely, the LM functions as a localiser, background, or referential entity and is construed as the relationship's static element or reference point. Their relationship is, therefore, asymmetrical. The two arguments are necessary for a lexical preposition to occur as a predication. For that reason, we postulate a Logical Structure of two elements (x, y), i.e., an argument structure (Jackendoff 1983; Van Valin 2005; Langacker 2008) consisting of two arguments, TR and LM (TRx, LMy).

Some spatial particles need two syntactically explicit arguments as some verbs do, for instance:

(1) *make* (x, y)
John made a cake
BUT **John made ø*

(2) at (x, y)
the milkman is at the door
**the milkman is at ø*

Other spatial particles may have arguments that are not necessarily expressed syntactically, though the arguments are conceptualised implicitly, as many other verbs do:

(3) eat (x, y)
Mary ate a cake
Mary ate ø.

(4) in (x, y)
The milkman is in the house
The milkman is in ø.

Examples (1) and (2) show that syntactically explicit arguments are necessary for *make* and *at* (also for *from, with, for, of*), whereas *eat* and *in* (also *on, above, beyond*, …) may be used in constructions with implicit arguments, as shown in (3) and (4). This distinction has been extensively expounded by Bierwisch (1988) and Kazimierz A. Sroka (1972), among others.

3.2 Situation structure

Aktionsart distinctions such as states, activities, achievements, semelfactives, accomplishments, active accomplishments, and causative accomplishments, as determined through event parameters such as +/− static, +/− dynamic, +/− telic, +/− punctual (Zeno Vendler 1967; Van Valin 2005) define the event structure of verbs. However, the conceptualisation of spatial relationships occurs in a summary scanning mode rather than a sequential scanning mode (Langacker 2013: 83, 111). Therefore, a spatial relationship is conceived as a situation rather than an event. The characterisation of the construal of the asymmetric relationship between TR and LM in terms of situation types (Simon C. Dik 1997) yields at least two possible situation types:

a. Position: The TR in the relationship is characterised as an agentive, intentional entity keeping control over the spatial relationship, adopting the positioner role. Examples (5) and (6) show a positioner TR controlling the spatial relationship with the LM.

   (5) *The fly at the piece of melon* *(licking)*

   (6) *The fly on my hand* *(walking)*

We contend that meaning is embodied in speakers' minds, not in the world. If the speaker uses "on" instead of "in", s/he is conferring the location of control on the TR.

b. State: The TR in the relationship is conceived as an entity that experiences a state because it is not conceived as holding control over the situation. Conversely, the LM is conceived as constraining the TR. Examples (7) and (8) show an experiencer TR.

   (7) *The fly in my hand* *(trapped)*

   (8) *The fly under the piece of melon* *(crushed)*

In terms of situation type – which can be seen as an aspect of construal – the relationship expressed by a relational predicate is asymmetric so that one argument is

privileged as primary, in terms of saliency, because it is conceived as dynamic. In contrast, the other one is conceptualised as secondary and stative. In any case, the salient participant (TR) may realise two different roles, either intentional (positioner) or passive (experiencer). If the speaker decides to use "on" instead of "in" for a situation that might be conceived in both ways, that decision confers the location of control on the TR. As Coventry (1998) argues, language users apply a mental model to interpreting a spatial scene so that the model confers a role to the TR. Our contention is that meaning is an embodied mental process in the language users' minds rather than a set of correspondences with world situations.

3.3 Perceptual structure

For the characterisation of lexical knowledge of nouns and adjectives, the generative lexicon theory posits some aspects of conceptualisation called qualia. These are characterised as properties associated with a lexical item which best explain what it means (Pustejovsky 1995: 76–81). Qualia (constitutive, formal, telic, and agentive) drive our understanding of an object or a relation in the world by showing semantic constraints that structure our knowledge of lexical items and may alter their denotation (Pustejovsky 1995: 86–87). The constitutive quale shows the relation between an object and its constitutive parts or its internal structure (material, weight), e.g., for a table, its material – wood and iron. The formal quale distinguishes an object within a larger domain (orientation, magnitude, shape, dimensionality, colour, position), e.g., for a table, its shape, legs, and board configured as a whole. The telic quale shows purpose and function, e.g., for a table, its use as support for meals or other uses. Finally, the agentive quale shows factors involved in an object's origin (creator, artefact, natural kind, causal chain), e.g., for a table, the carpenter or manufacturer and how it comes into existence. Every category expresses a qualia structure, though not all lexical items carry a value for each quale role. Qualia structure tells us the semantic constraints by which we understand a word when using it. Qualia provide the structural template over which semantic transformations may apply to the denotation of a lexical item, i.e., suggest interpretations of words in context.

From an embodiment perspective, we consider perceptual parameters of spatial relationships as analogous to qualia in nouns and adjectives. Thus, the attributes revealed by linguists (see Section 2) in the spheres of geometry, topology, force dynamics, and function can be organised as four perceptual parameters configuring spatial relationships analogously to the four qualia. The conception that the meaning of prepositions may be described as a configuration of parameters has been proposed by Deane (1993, 2005), Michele I. Feist (2000), and Gärdenfors (2015), among others. Deane posited three types of perceptual

space: visual space, manoeuvre space and kinetic space. Feist posited four *attributes*, geometry, function, qualitative physics, and animacy of the participants. Gärdenfors, in turn, distinguishes between visuospatial and force *domains*. Though Deane's spaces, Feist's attributes, and Gärdenfors' domains do not coincide precisely with the parameters and values proposed here, all these proposals share the idea that each parameter (space, attribute, or domain) may display diverse values and that these values are conditions for use as speakers may sanction one or more by conceiving a spatial scene for communication. In none of these accounts of spatial relation meanings are these parameters and their values necessary and sufficient conditions for using a preposition to express a spatial scene. In addition, just one of the parameters' values might be enough to sanction the use of a preposition to depict a particular spatial scene.

In our view, geometry may be regarded as the constitutive parameter of spatial relationships, the bare location consisting of dimensions (0D, 1D, 2D, 3D), planes and axes, the vertical axis defined by gravity and the horizontal one defined by the ground (Clark 1973; Regier 1996). Gärdenfors (2015) describes space as three dimensions, height, width and depth, introducing additional values like polar coordinates, convexity, vectors, and angles of vision.

Topology is analogous to formal aspects since it constructs the relative configuration of the participants' spatial regions. Any conceptualisation of a spatial TR-LM configuration is based on human visual patterns that offer a scheme for the spatial arrangement of perceived situations (Talmy 1983, 2000, 2003). Thus, the participants are construed as bearing a relationship of coincidence, contiguity, contact (attachment, adjacency), inclusion, proximity, distance (proximal, medial, distant), intersection, sequence, relative size (TR=LM; T<LM), relative orientation (parallel, perpendicular, oblique), alignment (face vs side alignment of active zones), reference frame – intrinsic, relative, absolute (Stephen C. Levinson 2003) – boundary, LM number (one, two, several), and vantage point (encompassing vs external).

The Force Dynamics parameter responds to the agentive kinaesthetic aspects of the relationship. Coventry & Garrod (2004) coined the term "dynamic-kinematic routines" as a label for the types of routines – different from geometric routines – computed when looking at spatial scenes. According to image-schematic force-dynamic gestalts (Johnson 1987; Talmy 1988), the participants' interaction, disposition and orientation concerning each other show a force-motion directionality (animacy, intentionality, relative orientation, motion, force, path). The degree of animacy, intentionality and agentivity of the participants plays a decisive role as far as the entities' relative function is concerned. A dynamic process may end up in a resultative topology (e.g., 'arrive at', 'put into', 'over the bridge'). This parameter may display alternative modes, like motion vs

stationariness, and diverse path contours, like straight, arced, circular, and meandering (Talmy 1983, 1988, 2000).

Finally, the functional parameter expresses the perceived interaction and mutual influence between the participants (telicity). A preposition may instantiate a sense of purpose, operation, control, benefit, protection, instrument, means, constraint, concealment, comparison, exposition, position, accessibility, visibility, relative priority, company, and others. These factors refer to the perceived consequence or effect of the relationship on the entities involved (Vandeloise 1991, 1994; Coventry 1998; Coventry et al. 1994; Coventry & Garrod 2004; Langacker 2010). In a series of experimental works, Feist & Gentner (1998, 2003, 2012) have shown that diverse classes of attributes (geometric, functional, and qualitative physical) influence speakers' choice of prepositions (see also Carlson-Radvansky et al. 1999). Feist & Gentner (2012: 308) advocate separating attributes by distinguishing geometry, function, locus of control, and animacy factors. They provide experimental evidence of these factors' independence as well as their interaction, as speakers make choices for usage.

The four parameters described in this section and their diverse alternative values form family resemblance sets for the meaning of each preposition. The instantiation of the four parameters in the semantic construal of a particular expression used in a single usage event signals the prototypical meaning of the spatial particle.

3.4 Lexical inheritance hierarchy

The Natural Semantic Metalanguage (NSM) (Wierzbicka 1996; Cliff Goddard & Anna Wierzbicka 2014) is a cognitive approach to meaning that uses a metalanguage of simple, cross-translatable terms as a method of representation. A set of semantic primes defines the lexical subdomains of the spatial relations lexical domain. Evidence suggests that semantic primes are shared human concepts and manifest as words or linguistic expressions in all or most human languages. Consequently, explications and scripts expressed in the NSM can be regarded as both linguistic and conceptual analyses. NSM (Goddard 2021) suggests the following primes as relevant for space, which may be relevant to define prepositions' lexical subdomains in LCM:

Place WHERE/PLACE, HERE, ABOVE, BELOW, FAR, NEAR, SIDE, INSIDE, TOUCH

Movement MOVE

(*change of location*: [BECOME *NOT be-LOC' (y, z)]

Intensifiers VERY, MORE (Lexical Functions *Plus* and *Magn* in LCM)

Here, we show preliminary formulations. We use the NSM list as an initial set of core terms for lexical subdomains in English. In our hierarchy, each core term is defined by a parameter value that all the lexical units in the subdomain share (T-proximal, T-distant, and so on). Each prime or core term defines a lexical subdomain. The semantic primes (understood as a universal NSM) are the core terms in capitals. The English prepositions (language specific) in italics are included in various lexical subdomains:

NEAR [T-proximal] (x, y): *near, at, by, about, in front of, behind*, …
FAR [T-distant] (x, y): *far from, away from, opposite*, …
TOUCH [T-contact] (x, y): *on, onto, against, on top of, across, to*, *through*, …
BELOW [T-lower $level_1$] (x, y): *below, under*, …
ABOVE [T-higher $level_1$] (x, y): *above, over*, …
INSIDE [T-interior] (x, y): *inside, in, into, within*, …

Lexical inheritance implies that the terms in the subdomain inherit the topology of the core term. In the formulations above, T stands for topology, and the $subindex_1$ indicates the first argument in the predication (TRx). Each superordinate term is used to formulate more specific lexical items or hyponyms, which inherit information from the superordinate term. The NSM terms NEAR, FAR, BELOW, ABOVE, and INSIDE should not be understood as equivalent to the English lexical units *near*, *far*, *below*, *above*, and *inside* within the lexical subdomains. Recent research suggests that the meanings of these lexical units vary across languages (e.g., Yuan Zhang 2013; Feist & Zhang 2019 for *inside*). Each NSM term is defined only by the parameter value expressed between brackets. However, the lexical units must be characterised by all the perceptual parameters plus further specifications in an LT.

4. Lexical templates

The LCM (Christopher S. Butler 2009; Mairal & Ruiz de Mendoza 2009; Ruiz de Mendoza & Mairal 2008b) uses the notion of LT for the lexical representation of predicates (Mairal & Faber 2007), proposing a syntactic-semantic system of representation of both lexical units and constructions. An LT is a low-level semantically enriched representation of the syntactically relevant content of a predicate meaning plus pragmatic and semantic information that constitutes that meaning. Its internal configuration results from the combination of lexical functions and semantic primitives. The model allows for the representation of lexical knowledge

of prepositions (see Navarro i Ferrando 2011, 2012) in the form of LTs compatible with other categories' LTs (i.e., verbs) and constructional templates (Ruiz de Mendoza & Mairal 2008a; Mairal & Ruiz de Mendoza 2008).

The LCM attempts to provide an adequate account of the syntax-semantics interface by identifying the aspects of meaning which determine alternative usage of predicates and investigating why certain predicates can participate in a given set of constructions while others cannot. Thus, LCM provides a semantic perspective on what kind and amount of information should be included in lexical representations. Therefore, the LT construct aims to stretch the chain of semantic decomposition as much as possible by improving a meta-language that has provided typologically valid representations for verbal and noun categories, as shown by other functional models like RRG. We hypothesise that the formalism proposed here may encompass semantic variability of spatial terms as shown in diverse typologically oriented studies (for cross-linguistic research on spatial terms' semantic variability, see, e.g., Eric Pederson et al. 1998; Levinson et al. 2003; Levinson & David P. Wilkins 2006; Feist 2008).

Here is the basic representational format for an LT:

> [SEMANTIC MODULE <lexical functions>] [AKTIONSART MODULE <semantic primes>] (thematic frame)

Lexical functions account for lexical domain-specific relationships and elements of world knowledge specific to the predicate defined by the LT. We assume that every lexical function within a prepositional LT correlates with one of the experiential attributes specified by spatial perceptual parameters (see Section 3.3). The Aktionsart module corresponds to the situation type of the prepositional construal in summary scanning mode. The semantic primes indicate the lexical subdomain and lexical inheritance in the lexical hierarchy. Finally, the thematic frame shows the participants' configuration as an argument structure consisting of TR and LM. Accordingly, the LTs described here for prepositional predicates will adopt the following form:

> [<Geometry LF>, <Topology LF>, <Force-Dynamics LF>, <Function LF>] [situation type <semantic prime>] (TRx LMy)

In the following, we discuss a set of prepositional predicates and their LTs. For the preposition *at*, the semantic decomposition of this predicate (Navarro i Ferrando 2002, 2006, 2011, 2012; Iwona Kokorniak 2007) results in the following LT:

> At [<G-0D, ground> <T-proximal, T-contiguity> <D-intentionality$_x$> <F-operation$_{xy}$, F-instrument$_y$>] [position <(*[BECOME be-LOC (x)]) NEAR>] (TRx, LMy)

The first element in the LT presents the lexical item under consideration. It is followed by a semantic module between square brackets presenting the semantic information relative to the lexical functions that specify the perceptual parameters of the particle. The second module between square brackets represents the situation type and the lexical subdomain in small capitals and includes information relevant to construction subsumption. At the end of the LT, the argument structure is represented between brackets.

The lexical functions in the semantic module represent values for the perceptual parameters expounded in Section 3.3. The information pertaining to each parameter is delimited by the symbol < >; commas separate the information pertaining to diverse specifications or values within each parameter. The first element in the semantic module expresses the geometry parameter. For the preposition *at*, the prototypical geometry (constitutive space) is defined by no dimensions (0D) and a horizontal axis that determines the alignment of the participants. The axis is denominated "ground" as opposed to the "gravity" axis that corresponds to vertical orientation. Two specifications fill the topological parameter (T) for this preposition's prototypical conceptualisation (proto-concept). The "proximal" value is shared by all the prepositions belonging to the subdomain NEAR in the lexical hierarchy. In addition, the value "contiguity" defines the topology (formal configuration) of this preposition, showing that TR and LM are conceived as contiguous to each other. As Coventry (1998) argues, language users apply mental models to the interpretations of spatial scenes, and here the lexical function *T-Contiguity* represents the mental model rather than the world situation. The use of "at" contrasts with the use of "near", "by", or "a few feet from the door" because the language user applies the mental model to interpret the *spatial scene*.

In the dynamics parameter (D), the lexical function "intentionality$_x$" indicates that the participant x (TR) is conceived as intentional in a prototypical spatial scene conceived by speakers as they use this preposition. The lexical function "intentionality" implies that intentional physical entities adopt a particular directionality or orientation towards the object of intention (the LM) and entails that the TR entity is conceived as animate, as a preference option. As an emergent semantic attribute for this preposition, speakers first acquire this parameter value by experiencing usage events where the TR is an animate being oriented to the LM with the intention of interacting with it. Thus, though the situation might provide an inanimate TR, in default cases, when the TR is indefinite concerning animacy – i.e., it might be conceived as either animate or inanimate – the preposition confers and prefers TR animacy.

Finally, the function parameter (F) shows the lexical function "operation$_{xy}$", indicating that participant x bears a functional relation of operation with partici-

pant y. The function "operation" is a transitive function where one participant is intentionally agentive towards another participant. This lexical function projects a purposive stance on the TRx, i.e., the first argument x (TR) is functionally oriented for some purpose. The function "instrument$_y$" indicates that the second argument (LMy) is functionally conceived as an instrument or artefact.

The term "position" shows the situation type expressed by this preposition. Notably, it specifies that the first argument (x) is construed as a positioner in relation to the LM (y), i.e., that the scene expressed by this particle implies control over the situation on the part of the TR.

The formula (*[BECOME be-LOC (x)]) shows the compatibility of this preposition with argument X's motion in motion constructions, only occurring with verbs expressing activity or active accomplishment *Aktionsart* (see Navarro i Ferrando 2011). The asterisk outside the square brackets, encircled between round brackets, indicates that this lexical unit is compatible with constructions and other lexical units expressing a change of location or argument X's movement. However, that motion is not expressed by this particular predicate on its own.

The argument structure includes two arguments, x and y. The former refers to the antecedent of the preposition and the latter to its complement, semantically construed as TR and LM, respectively. The semantic prime NEAR expresses that this preposition belongs to a lexical subdomain of relational predicates where the relationship designates proximity between the participants.

Let us illustrate the interpretation of the LT by taking examples (9) and (10) as usage event instantiations:

(9) *The woman sat* ***at*** *the table*

(10) *The woman sat down* ***at*** *the table*

By conceptualising the scene in (9), the language user conceives of two participants, "woman" and "table", where the woman is more salient (TR) and localised with reference to the table (LM). The axis used for their localisation is the ground axis (horizontal), but no further geometric dimensions are necessary (0D) for the scene to be perceived or the spatial relationship to be conceived. Topologically, TR and LM are proximal to each other, and therefore, the preposition *at* is subsumed in the lexical subdomain defined by NEAR. In addition, their topology is specified by the value "contiguity", which implies the woman may reach a region or active zone of the table without needing to change her location. The woman's intentionality prompts her orientation and directionality facing the table. The woman is in functional interaction with the table by carrying out actions whereby she uses the table for some purposes. The situation type is a "position", given that the woman controls herself and her location in relation to the table.

Example (10) shows a usage event of a motion construction where the woman moves, ending up in a location specified by the modules and components in the LT. So, the motion parameter [BECOME be-LOC (x)] applies here.

Concerning the preposition *on* (see Navarro i Ferrando 1998, 2006, 2011, 2012), the following LT represents its semantic decomposition:

> On [<G-2D, gravity> <T-contact> <D-intentionality$_x$> <F-control$_x$, F-support$_y$>] [position <(*[BECOME be-LOC (x)]) TOUCH>] (TRx, LMy)

The LT shows that the scene locates a TR and an LM in a geometric space where two dimensions are relevant, and the axis for conceiving them is the vertical axis, defined by the effect of gravity on Earth. The gravity axis is relevant because the scene depicts a participant (TR) counteracting the effect of gravity. The topology shows that the participants are conceived as in contact with each other. The TOUCH semantic prime indicates that this preposition belongs to a lexical subdomain defined by this condition. The dynamics parameter shows the TR's intentionality. This value coincides with the dynamics of the preposition *at*. Thus, in terms of the dynamics of the scene, both prepositions share an originally animate, intentional TR adopting a particular directionality towards the LM. That orientation is framed by the ground axis for *at* and the gravity axis for *on*. Otherwise, these prepositions differ in the function parameter. The lexical function "control$_x$" indicates that the TR controls its location, and "support$_y$" specifies that the LM provides support. These two functions entail a continuative situation. The fact that the preposition *on* suggests a continuative scene does not derive from the contact topology since contact may be punctual in any conceived scene. Neither derives the sense of continuation from the "intentionality" lexical function because intention and directionality just determine orientation and force. The function parameter suggests a continuative situation, given that both keeping control and supporting require a durative scene. These are experiential correlations; therefore, no additional lexical function is necessary for the LT to express this nuance of meaning (continuative-ness).

The role of the TR in the situation is that of a "positioner" in coherence with the "intentionality" and "control" values in the semantic module. This preposition is compatible with motion constructions expressing the TR's movement, only with verbs expressing active accomplishment *Aktionsart* – otherwise *onto* is used (see Navarro i Ferrando 2011). The thematic structure involves two arguments, as is expected for the set of prepositions.

Example (11) shows a usage event where the contact topology is emphasised. The TR (man) is intentional – also animate in this usage event – and directs its action to maintain contact with the LM (teacup). The man, by metonymy (also *hands*), is the positioner in the situation and keeps control of the conceived loca-

tion, the teacup being the functional supporter for that location. In contrast with *at*, where the intentionality is directed to operate some action by using the LM, for *on* the location is conceived as a space for support, controlled by the TR, to counteract the effect of gravity.

(11) *The man was warming his hands* ***on*** *the teacup.*

In the same fashion as in (10), Example (12) illustrates the use of a motion construction where the TR's motion is added by the construction so that it reaches the location specified by the prepositional LT.

(12) *The aeroplane landed* ***on*** *the landing track.*

Regarding the preposition *in* (Ariadna M. Drozdowicz 1998; Navarro i Ferrando 2000), we propose the following LT:

> In [<G-3D, gravity, ground> <T-inclusion> <D-constraint$_{yx}$> <F-reclusion$_{yx}$, protection$_{yx}$] [state <(*[BECOME be-LOC (x)]) INSIDE>] (TRx, LMy)

For *in*, the geometry parameter encompasses the three dimensions of space and two axes. This comprehensive configuration derives from the complexity of the relationship involving an LM's extensive active zone and the TR as a whole. In topology, "inclusion" is a multifaceted configuration involving the interior zone of the LM where the TR is located with no mainly profiled active zone. The inclusion value implies that (1) the TR's relative size is smaller than the LM's (TR<LM), and (2) the LM's interior comprises a space for the TR to be located. (1) and (2) result as entailments of the container schema (George Lakoff 1987: 272–273) so that the language user's mental model prefers a smaller TR and a larger LM in default cases. This location has consequences for the force-dynamic interaction between the participants. In the dynamics parameter, the lexical function "constraint$_{yx}$" shows that the LM (y) constitutes a blockage area for the TR (x) by counteracting the TR's attempts – if any – to leave the interior space (this lexical function would license the use of in in *the bulb in the socket* (see Vandeloise 1991). Perceptually, as an enactive emergent meaning, the functional parameter is the most relevant for this preposition (Feist 2000: 208). The lexical function "reclusion$_{yx}$" points out the role of the LM as influencing the TR's potential action through physical constraint. Moreover, this parameter incorporates an idiosyncratic lexical function, "protection$_{yx}$", resulting from human experiential embodiment. The protective function of containers constitutes clear evidence of the enactive meaning hypothesis by showing that experiential perceptual phenomena impinge our conception of spatial relationships. The human sensation of feeling

protection is not a property of Euclidean space but is part of the conceptualisation in many usage events of the preposition *in*.

The situation type is a "state" rather than a "position", considering the experiencer role incarnated by the TR. The preposition *in* is compatible with motion constructions only with verbs expressing activity or active accomplishment *Aktionsart* – otherwise *into* is used (see Navarro i Ferrando 2011), a fact indicated by the formula [BECOME be-LOC (x)].

In (13), it is appreciated that all dimensions of space and experiential axes are necessary to conceive of the relationship between an entity (lizard) and a container (glass box). Topological inclusion affects the TR as a whole entity and is conceived as perceived spatial subsumption of the TR by the LM, i.e., the TR occupies the same space as the LM. Here, the force-dynamic constraint exerted by the glass box impedes the lizard's movement beyond the containment space. Reclusion_{yx} and protection_{yx} account for the effects of the lizard's topological inclusion in the glass box as conceived by a human conceptualiser. The prime INSIDE illustrates the lexical subdomain for all prepositions instantiating the container image schema. The two participants realise the argument structure, namely, the lizard (TRx) and the glass box (LMy).

(13) *The lizard is in the glass box*

Example (14) shows a usage event where the preposition *in* is used in a caused-motion construction co-occurring with a verb (put) expressing an active accomplishment *Aktionsart*.

(14) *The child put the toy in the box*

The semantic values specified for each parameter in the LTs described here (*at*, *on*, *in*) are prototypical values constituting sets of family resemblance attributes for each category rather than requirements for each predicate to be instantiated in every single usage event. Once the information in each of the parameters of the LT for a particular lexical unit is specified, the result represents the predicate's prototypical semantic structure, ruling out elaborations, shifts, or metaphorical extensions. These occur under the effect of external constraints or pragmatic effects and do not constitute our object of analysis here. Concerning subsumption, this proposal for the decomposition of meanings is compatible with the metalanguage used for constructional templates and verbal LTs in LCM.

5. Conclusions

We have illustrated the semantic decomposition of three prototypical prepositions using the LT formalism proposed by LCM. The semantic information included in these LTs intends to represent the language users' lexical knowledge of these lexical units and endeavours to be comprehensive of the semantic descriptions produced by cognitive linguists in recent decades, particularly the enactive meaning approach. The goal was, therefore, not a new proposal on the polysemy of prepositions but rather a formalisation of the prepositional lexical knowledge proposed in the cognitive embodiment approach. This formalisation makes prepositional lexical meaning representation suitable for lexical constructional subsumption analyses in the Lexical Constructional Model.

The LTs described for prepositional units consist of argument structure, situation structure, lexical inheritance hierarchy and perceptual parameters, including geometry, topology, force dynamics and function. We propose that the scheme may provide the necessary semantic clues to understand and explain the prototypical construal of spatial scenes expressed by speakers in usage events of these prepositions referring to the physical domain. The parameters described may constitute a grounded basis for establishing experiential correlations with further facets of spatial experience as perceived and conceptualised by language users for the purpose of language use.

Further research may show how formal and content cognitive operations work on these parameters and their values in the metaphorical mappings of figurative uses of prepositions (María Sandra Peña-Cervel & Ruiz de Mendoza 2022). The lexical knowledge described through these LTs allows for making evident experiential correlations that provide a ground for spatial correlation metaphors. It also provides conceptual material for making evident resemblance mappings of spatial prepositions onto abstract domains. A further step is to investigate subsumption constraints of spatial particle predicates in various constructions since constructions like caused motion do not license all verbs. Recent experimental research (Breaux & Feist 2010) shows that prepositions differ in their distribution, frequency, and semantic combinatorial possibilities, which constructional patterns may also condition. We could start by checking which spatial particles occur and which do not in motion constructions and see whether a particular preposition licenses certain verbal *Aktionsart* types in these constructions. Preliminary observations (Navarro i Ferrando 2012) suggest that *into* and *onto* license some stative verbs in the caused-motion construction (e.g., *she scared him into a depression*). Since spatial particles contribute relational meaning (like verbs), some constructions could encompass a primary and a secondary predication, each displaying an argument structure. In our view, spatial particle predications need

two arguments (TR and LM) that other relational predicates could share in a single construction.

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Abbreviations

CG Cognitive Grammar
fMRI functional Magnetic Resonance Imaging
LCM Lexical Constructional Model
LF Lexical Function
LM Landmark
LT Lexical Template
MEG Magnetoencephalography
RRG Role and Reference Grammar
TR Trajector

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