

Characterizing semantic memory loss: Towards the location of language breakdown

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Abstract. Patients suffering from various types of dementia usually present an impaired performance with specific categories like animals, furniture, etc. This impairment is known as category-specific semantic deficit and can provide us with vital information as to how the conceptual-semantic knowledge is stored and organized in the brain. Until date, no theoretical model has been able to appropriately account for the unsystematic and varied patterns of category-specific semantic deficits found so far. Moreover, there seems to be no correlation between the type of brain damage and the pattern of memory loss, nor can the latter be accounted for by any of the so far proposed models of conceptual knowledge representation and storage in the brain. Our purpose is to adapt and provide a theoretical model that builds on FunGramKB ontology and helps understand and properly interpret the available empirical data. The advantage that comes from the use of this complex theoretical model is that it will allow us to pinpoint the break of the conceptual chain, providing a more accurate measure of the location of the semantic memory loss.

Keywords: Semantic memory; category-specific deficit; dementia; ontology.

[es] Caracterización de la pérdida de la memoria semántica: hacia la localización del deterioro lingüístico

Resumen. Los pacientes que padecen distintos tipos de demencia generalmente presentan una disminución en el rendimiento con categorías específicas tales como animales, mobiliario, etc. Este deterioro se conoce como deterioro semántico de categorías específicas y nos puede proporcionar información vital en cuanto a cómo el conocimiento conceptual semántico se almacena y se organiza en el cerebro. Hasta la fecha, ningún modelo teórico ha sido capaz de explicar adecuadamente los patrones no sistemáticos y variados de los deterioros semánticos de categorías específicas encontrados por el momento. Por otra parte, parece no haber ninguna correlación entre el tipo de daño cerebral y el patrón de pérdida de memoria, ni tampoco puede este último ser explicado por los modelos existentes sobre la representación del conocimiento conceptual y el almacenamiento de la información en el cerebro. Nuestro propósito es adaptar y proporcionar un modelo teórico que se basa en la ontología de FunGramKB, y que ayuda a comprender e interpretar adecuadamente los datos empíricos disponibles. La ventaja de utilizar este modelo teórico es que nos permite detectar la ruptura de la cadena conceptual, proporcionando una medida más precisa de la localización de la pérdida de la memoria semántica.

Palabras clave: Memoria semántica; deterioro de categorías específicas; demencia; ontología.

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1. Introduction

Patients suffering from various types of dementia (e.g. Alzheimer's disease, mild cognitive impairment, semantic dementia) and aphasias usually present an impaired ability to identify specific categories of objects. This ability can be selectively impaired. For example, an individual may have a compromised performance in certain tasks when living things are involved, e.g. fruits and animals, while her performance remains relatively intact when other non-living thing categories like furniture and clothes are involved. Hence, this impairment is known as *category-specific semantic deficit* (Capitani et al. 2003; Peraita & Moreno 2003; Laws et al. 2007; Pérez Cabello de Alba 2017, among others). This kind of cognitive deficit is crucial since it can provide us with vital information as to how semantic knowledge is stored and organized in the brain (Capitani et al. 2003).

In the literature, a great amount of data can be found that supports the existence of category-specific semantic deficits in cases of brain damage. In fact, different authors have identified very different patterns of selective impairment (see Laws et al. 2007; Peraita & Grasso 2010; Rodríguez Rojo et al. 2015, to name but a few). Usually, such patterns can not be accounted for by the type of brain damage. This is so because often, patients with a type of dementia in one study present a specific selective impairment, such as problems with living things, whereas in another study, a group of patients with the same type of dementia present the reverse impairment (i.e. problems with non-living things and no problems at all with living things). Besides, recent studies have identified a series of nuisance variables, like item familiarity, that account for much of the effect found in category-specific semantic deficits. Nevertheless, this selective deficit seems to exist even when all the nuisance variables have been controlled (Bunn et al. 1998; Cree & McRae 2003; Laws et al. 2007, Moreno-Martínez & Rodríguez Rojo 2015).

Until date, no theoretical model has been able to appropriately account for the unsystematic and varied patterns of category-specific semantic deficits found so far. Thus, our purpose here is to provide and adapt a theoretical model that helps understand the available empirical data on semantic memory loss by locating the language breakdown along conceptual chains that are already defined in an existing ontology used for multiple purposes in Natural Language Processing (NLP) applications: FunGramKB (Periñán-Pascual & Arcas-Túnez 2010, 2011; Periñán-Pascual 2013). We have used this ontology because of its deep semantics foundation: the elements of the ontology are defined both in

relation with other elements of the ontology and also through predications that encode their perceptual, functional, and taxonomical features. Thus, FunGramKB allows the formulation of the ontology as a complex network of conceptual chains defined after several types of relations among the elements of the network and the properties of the concept that is encoded. If we can locate the semantic break in this network of conceptual chains, not only will we be able to account for the data that have already been found in the literature, but we will also be laying the ground for future work intended to predict how the semantic damage affects the whole conceptual network and, hopefully, how its evolution will be.

2. Dimensions of conceptual knowledge organisation in the brain

As noted above, the literature has observed that whereas some conceptual categories are damaged in a group of patients suffering from diverse neurological pathologies, others are relatively maintained. Examples of such categories are living things like animals, persons and plants, and non-living things such as tools, musical instruments, etc. The fact that subjects' performance in different tasks involving these and other categories shows differential impairment can be interpreted under the light of different theories of conceptual knowledge organization and representation in the brain.

Beyond the classical models for semantic memory like the semantic networks by Collins & Quillian (1969) and Collins & Loftus (1975); the componential theories by Katz & Fodor (1963); the prototype theory by Rosch (1978); and the connectionist models like the micro-features theory by Hinton & Shallice (1991) and Plaut & Shallice (1993), nowadays, there are two main approaches to the encoding of semantic knowledge in the brain: theories based on the neural structure principle and theories based on the correlated structure principle (Capitani et al. 2003).

The approach based on the neural structure principle argues that conceptual knowledge is organised in the brain and, that this organisation reflects representational constraints imposed by brain conditions: neural structure, semantic structure, syntactic structure, etc. The Sensory/Functional Theory (Humphreys and Forde, 2001) and the Sensory/Motor Theory (Martin et al. 2000) belong to this group and defend that conceptual knowledge is distributed across different modality-specific semantic subsystems, each dedicated to storing and processing a specific type of information (like the Chomskyan Faculty of Human Language). The Domain-specific Account (Santos & Caramazza 2002) also defends the existence of dimensions in which the conceptual knowledge is organised in the brain but these dimensions are thought to be modelled after evolutionary history, resulting in domain-specific neural circuits dedicated to survival problem solving. Hence, candidate domains are animals, conspecifics, etc. All these theories have one common claim: damage to one category will equally affect all the concepts belonging to that category

The approach based on the correlated structure principle defends, on the other hand, that there is no organisation of the conceptual knowledge in the brain. Instead, this is just an epiphenomenon derived from the statistical co-occurrence of the properties of the different objects to be found in reality. One of these theories is Caramazza et al.'s (1990) *Organised Unitary Content Hypothesis*, which defends the idea of an uneven conceptual space where the closeness of the concepts depends on the amount of properties that are shared by them. There is, thus, no semantic organising principle holding in the conceptual space of the brain. Its structure just reflects the degree to which properties of the objects tend to co-occur in the world. It is hypothesised too that concepts that are represented close to one another are encoded by neurally continuous clusters that are susceptible to be damaged, which accounts for the selective brain damage phenomena.

The approaches based on the correlated structure principle resemble Wittgenstein's (1953) family resemblance in that the members of families share properties, which is the basis of other very well-known theories of human categorization like Rosch's (1978) Prototype Theory. Rosch's approach, as well as all the ones based on the correlated structure principle, succeeds in codifying the observed fact that concepts like 'bee' and 'honey' are more related in reality than 'spider' and 'honey' are. The more related the concepts are in reality, the more closely they should be represented in the brain. The correlated structure principle accounts for the horizontal dimension of human conceptualization.

Additionally, in line with Rosch (1978), there is a second dimension that is defined by an economy principle: human beings try to gain as much information as possible with the least cognitive effort. The economy principle underlies the formation of inclusiveness chains organised in three kinds of levels, namely, basic, subordinate and superordinate levels. The first is the most salient level from a cognitive and linguistic point of view, and it encodes behavioural interaction patterns, thus giving rise to a real and clear image of the category. The superordinate level encodes very general properties, most often functional roles. It is a collector level in the sense that it sorts and classifies basic-level categories. Finally, the subordinate level codifies different subtle properties that distinguish different kinds of members that belong to the same basic-level.

Besides the aforementioned theories, there are other theories that account for both the horizontal and vertical dimensions of human conceptualization. One such example is Martín-Mingorance's (1998) Lexematic Functional Model, which captures both the horizontal dimension in different fields, and the vertical dimension through the different inclusion levels on which concepts are included and related to one another by means of different relations like hypernymy, hyponymy, synonymy, and antonymy. This is one of the deepest theoretical foundations of the FunGramKB ontology that we will introduce in section 3, and propose to apply in section 4.

3. The FunGramKB ontology

3.1 Theoretical foundations

The Functional Lexematic Model (FLM), developed by Martín-Mingorance (1998), integrated Dik's (1978a, 1978b, 1989, 1997) Functional Grammar (FG) (1978, 1989) and Coseriu's (1977, 1981, 1992) Lexematics. One of the main advantages of the FLM was the onomasiological organization of the lexicon, which thought of the lexicon as divided in semantic fields, established a hierarchical architecture, and described the paradigmatic and syntagmatic axis of the lexicon. In the paradigmatic axis, the lower terms of the hierarchy, called hyponyms, were defined by their more generic term or archilexeme. On the other hand, the syntagmatic axis adopted FG's description of terms by means of predicate frames. A basic idea in Dik's FG is that a predicate is never an isolated item, but always a structure in the sense that predicates exist only as part of predicate frames, which define not only the form, but also the type and the quantitative and the qualitative valency (participants) of the predicate (Dik, 1997:2).

Later, the Lexical Grammar Model (Faber & Mairal 1999, Mairal & Van Valin 2001, Pérez Cabello de Alba 2005, among others) adopted a lexicon articulated in lexical classes and organized in meaning hierarchies, where inheritance mechanisms played a key role: a lexical item inherits or shares certain properties of another lexical item with which it is somehow related. This model made use of lexical templates, which encompassed the semantic and syntactic information of verbs. Those lexical templates showed the logical structure of the predicates, which was adopted from Role and Reference Grammar (Mairal & Van Valin 2001), showing the different dimensions of the predicates that consisted of two types of variables: external and internal. External variables are those aspects of the meaning of a word that are realized syntactically; internal variables are those semantic parameters which characterize an entire lexical class.

The literature on FunGramKB acknowledges both Role and Reference Grammar (RRG) (Van Valin 2002, 2005; Van Valin & LaPolla 1997) and the Lexical Constructional Model (LCM) (Ruiz de Mendoza and Mairal 2008, 2010, Mairal and Ruiz de Mendoza 2009) as the linguistic frameworks on which the lexical and grammatical modules of the knowledge base are grounded. For a more detailed account of the literature on the premises used to build FunGramKB, we address the reader to <http://www.fungramkb.com/>. As represented in Figure 1, The LCM is a comprehensive model of meaning construction which provides the analytical tools to account for those aspects of meaning construction that go beyond grammar, i.e. implicational, illocutionary and even discourse features. Since the outcome of this model is a fully-fledged semantic representation, this model was a good candidate for the development of natural language processing applications and it was implemented as part of FunGramKB, a multipurpose lexico-conceptual knowledge base designed to be used for different Natural Language Processing tasks, as we will discuss below (Periñán-Pascual 2013; Periñán and Arcas 2005, 2007a, 2007b, 2010, 2011; Mairal and Periñán 2009, 2010).

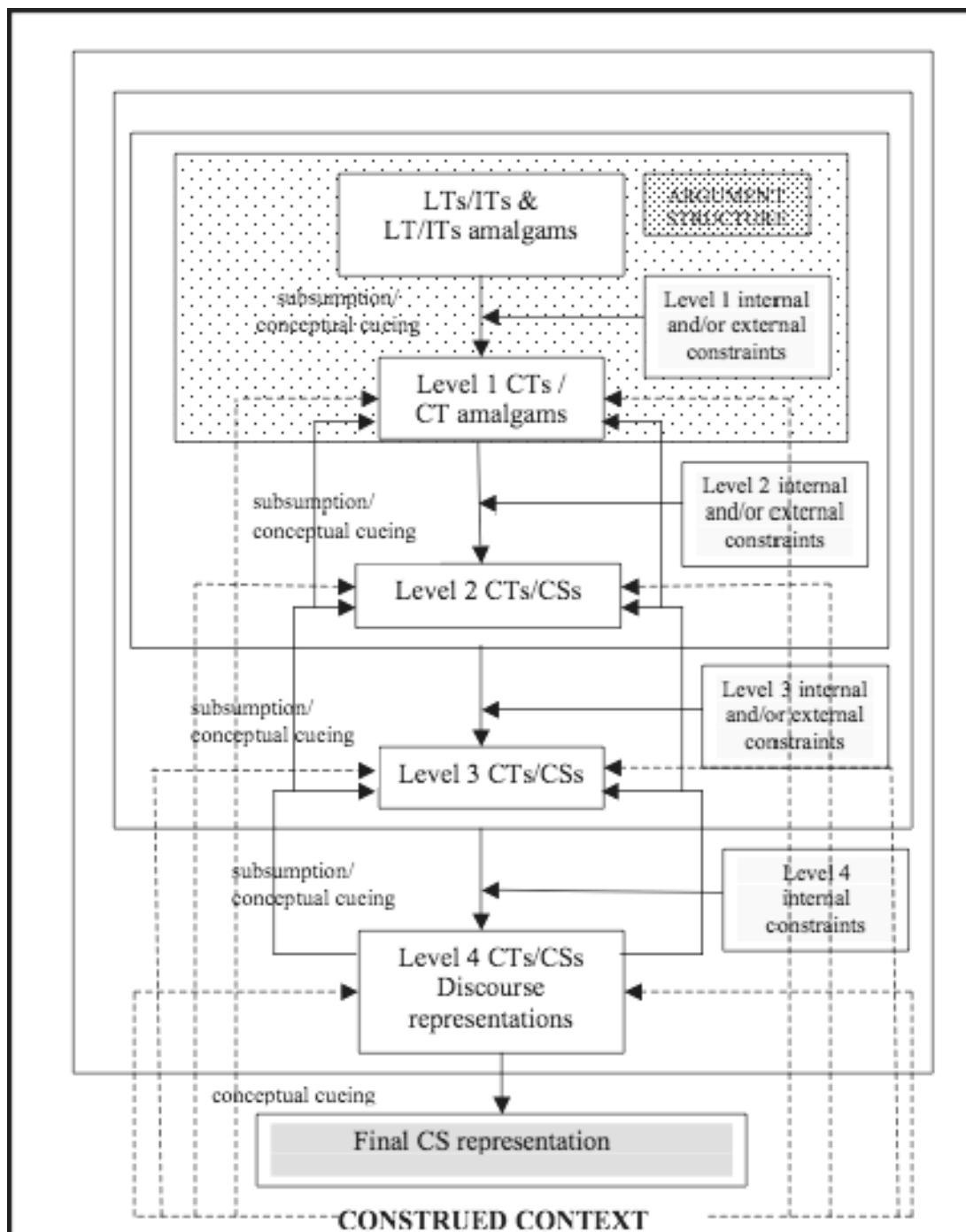
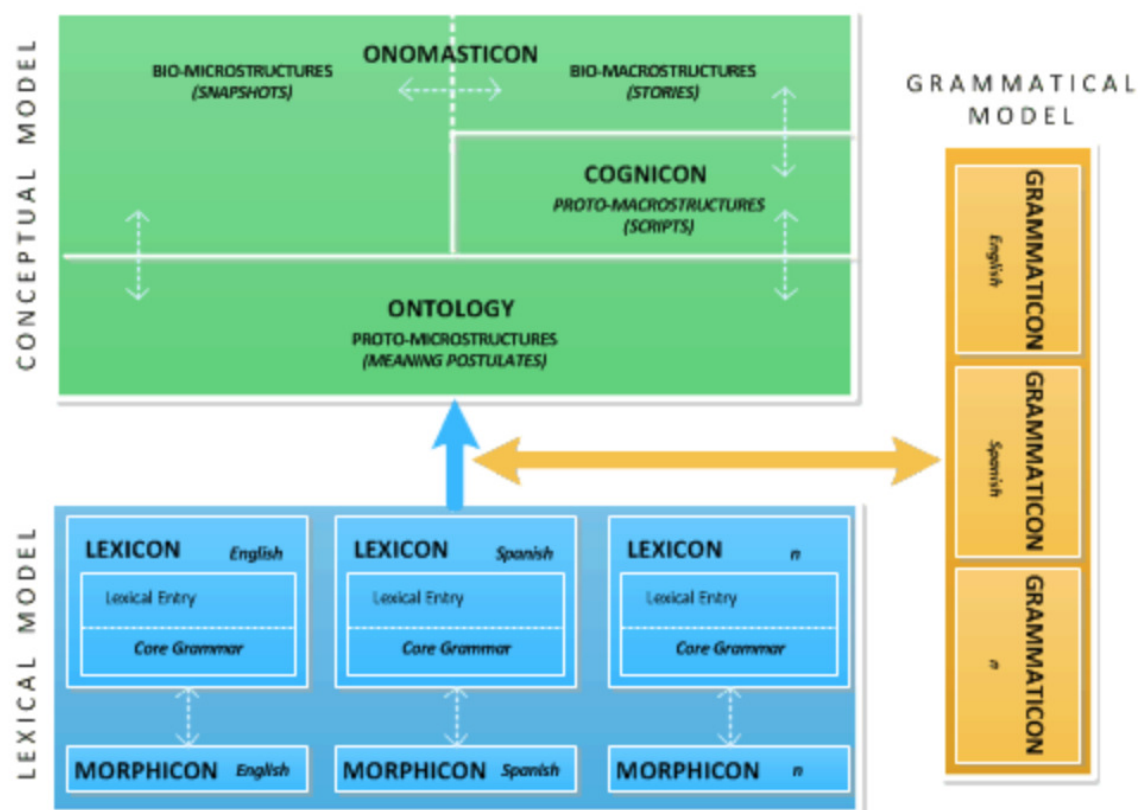


Figure 1: The architecture of the Lexical Constructional Model (Ruiz de Mendoza and Mairal 2008, 2010). LT = lexical template; IT = idiomatic template; CT = constructional template; CS = Conceptual Structure

3.2 The ontology

FunGramKB is a multilingual and multipurpose lexico-conceptual knowledge base designed to be used for Natural Language Processing tasks. It has three levels of information, which are represented in Figure 2 below: a lexical level which

includes a Lexicon and a Morphicon for each of the languages supported; a grammatical level, which contains the Grammaticons which are also language specific; and, finally, a conceptual level, which is shared by all languages. The conceptual level contains general knowledge in three subcomponents: (i) *the Ontology*, which is a hierarchically organized catalogue of concepts that humans have in their mind and which therefore reflects the model of the world shared by a community (Mairal Usón & Periñán-Pascual, 2009). Therein semantic knowledge is stored in the form of thematic frames, and meaning postulates; (ii) *the Cognicon*, where procedural knowledge is gathered by means of *script-like schemata* (cognitive macrostructures); and (iii) *the Onomasticon*, where instances of entities and events are stored through *snapshots* and *stories*. Thematic frames are the prototypical cognitive scenarios of events, which indicate the number of participants involved and, sometimes, they also contain the selection restrictions set on the participants of the event. Meaning postulates contain semantic information that is essential to define the properties of a specific concept, whether it be an event, an entity or a quality. As showed in Figure 2, both the lexicon and the



grammaticon are connected up to the cognitive level and they retrieve information from there. Thus, the explanatory scope of lexical entries is increased since encyclopaedic knowledge, present in the conceptual level, can be accessed.

Figure 2: The modules of FunGramKB modules (Periñán-Pascual and Arcas-Túnez, 2011: 3)

Since the focus of this study is semantic memory, which is represented by the ontological module in FunGramKB, we are going to focus only on the ontology. A complete description of FunGramKB can be found in the works by Periñán Pascual & Arcas Túnez (2011) and Mairal (2012).

An ontology is a hierarchical structure made up of universal conceptual units which hold inheritance and inference relations among each other. FunGramKB ontology is a three-layered conceptual model that comprises three types of concepts, where each one of them corresponds to a different conceptual level, going from the more general to the more concrete: (i) metaconcepts; (ii) basic concepts and (iii) terminal concepts.

Metaconcepts constitute the upper level in the taxonomy, they are preceded by symbol # and they represent cognitive dimensions (e.g. #ABSTRACT, #PHYSICAL, #OBJECT, #FEATURE, #COGNITION, #COMMUNICATION, #CREATION, #EMOTION, #MOTION, #TRANSFORMATION, etc.). There are three root metaconcepts: #ENTITY, #ATTRIBUTE and #EVENT, which correspond to the type of subontology addressed. Metaconcepts are not linked to any lexical unit. On the other hand, basic concepts are used as defining units which enable the construction of meaning postulates for basic concepts and terminal concepts. They are also used as selectional preferences in thematic frames. They are preceded by symbol +. Finally, the terminal level is not hierarchically structured and terminal concepts are supplied with a series of properties. They are preceded by symbol \$, and they cannot take part in meaning postulates.

It is important to highlight that FunGramKB is based on deep semantics. This implies that concepts establish inheritance and inference relations among each other, and also, each concept is individually defined by one of two properties: a Thematic Frame (TF) which indicates the number and type of participants involved in an event, and a Meaning Postulate (MP) which contains semantic information that is essential to define the properties of a specific concept. On the other hand, we say that it is linguistically motivated because in order to create a concept in the ontology, there must exist at least one lexical unit in a given language that is not already defined by any of the existing concepts in the ontology. The semantic information contained in the MP of concepts shows the connection among different conceptual units, and, in this way, their meaning postulates make it possible to establish relations among concepts.

As proposed in Pérez Cabello de Alba (2017), we can use FunGramKB ontology for the description of semantic categories in order to establish enriched conceptual networks which would reflect (a) inheritance relations, i.e. the onomasiological structure of concepts, and (b) inference relations, i.e. the concepts a given conceptual unit is linked to through its meaning postulates. More specifically, by using meaning postulates (MMPP) we can help in identification tasks of memory loss. We could for instance detect the point of the conceptual route where a breakdown is produced, which is what we will put forward in the next section. We could also evaluate whether the loss of a given predication would affect other concepts associated by means of a relation of inference. So, for instance, if we find a given feature such as +PET_00 in the meaning postulate of +DOG_00, and we have the same feature in another concept such as +CAT_00, we can assume that if someone is asked to name different types of pet animals, they will say both *dog* and *cat*.

By way of example, in FunGramKB ontology, a concept like ‘dog’ will have the following hierarchical representation:

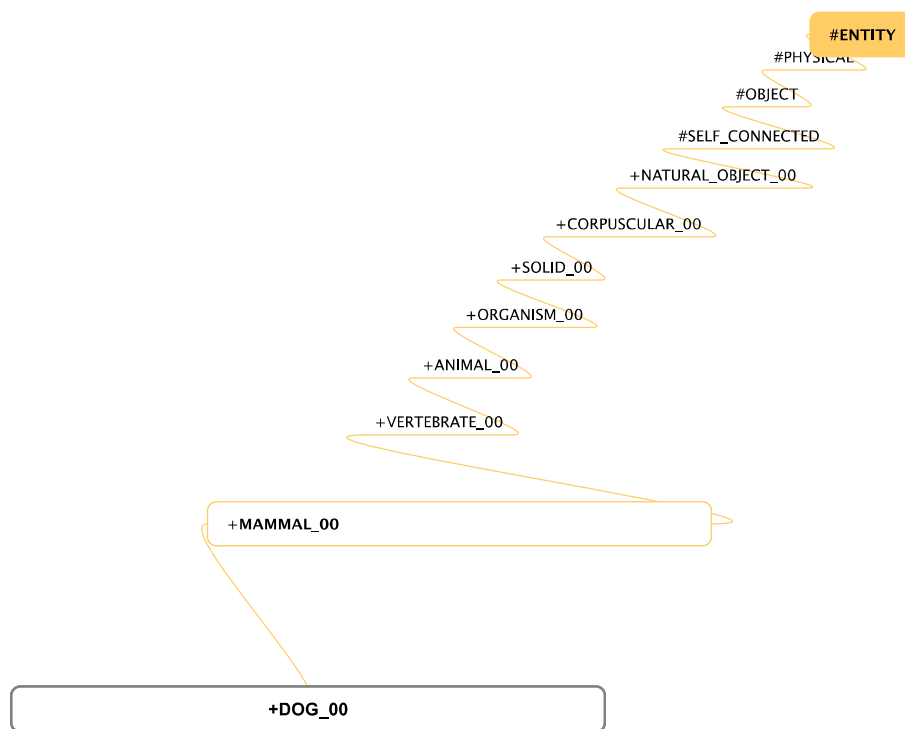


Figure 3: Conceptual chain of +DOG_00

In Figure 3 we see that the concept +DOG_00 is defined, going from the most general to the most specific conceptualization, as an entity (#ENTITY), which is physical (#PHYSICAL), is an object (#OBJECT), is self-contained (#SELF_CONNECTED_OBJECT), is a natural object (+NATURAL_OBJECT_00), is corpuscular (+CORPUSCULAR_00), is solid (+SOLID_00), is an organism (+ORGANISM_00), is an animal (+ANIMAL_00), is a vertebrate (+VERTEBRATE_00), and is a mammal (+MAMMAL_00).

As we have previously said, metaconcepts play a role of hidden categories used as superordinates in order to avoid circularity among definitions of concepts lower down in the hierarchy, and they are not linked to any lexical unit. In Figure 4 we show the hierarchical arrangement of the metaconcepts that play a role in the definition of +DOG_00.

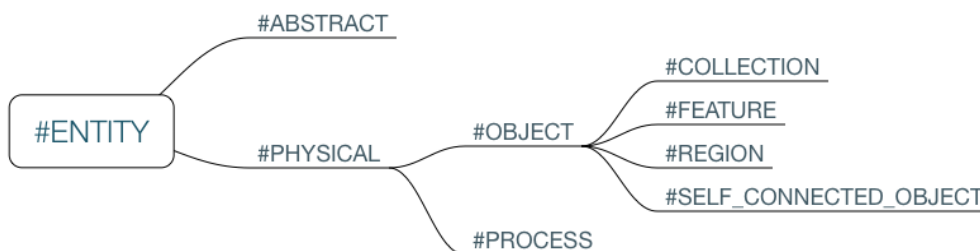


Figure 4: The Ontology of entities

On the other hand, we have said that the description of basic or terminal concepts is made by means of meaning postulates. A meaning postulate is made up of one or more connected predications, which carry the generic features of the concept. If a predication is preceded by the symbol “+” it means that it is always the case, and we call it “strict predication”; on the other hand, if it is preceded by the symbol “*”, it means that, although that is a typical feature of the concept, it does not have to be always true, and it is called “defeasible predication”.

By way of illustration, we present the editor interface of FunGramKB in Figure 5, where the predications that are part of the meaning postulates of the concept +DOG_00 can be seen:

The screenshot shows the FunGramKB Editor interface. On the left, there is a hierarchical ontology tree with 1174 entities. The tree is expanded to show the concept +DOG_00, which is a sub-concept of +MAMMAL_00. The central panel displays the conceptual information for +DOG_00, including its superordinate (+MAMMAL_00) and its meaning postulates. The meaning postulates are encoded in the COREL language. The bottom section shows the multilingual translation of the concept +DOG_00 into English (dog), Spanish (can, chuco, perro), and Italian.

CONCEPT:	+DOG_00 <input checked="" type="checkbox"/>
SUPERORDINATE(S):	+MAMMAL_00
SEMANTIC TYPE:	
MEANING POSTULATE:	<pre> +(e1: +BE_00 (x1: +DOG_00)Theme (x2: +MAMMAL_00)Referent) *(e2: +BE_01 (x1)Theme (x3: +TAME_00)Attribute) *(e3: +EAT_00 (x1)Agent (x4: +MEAT_00 ^ +BONE_00)Theme (x5)Location(x6)Origin (x7)Goal) *(e4: +BE_01 (x1)Theme (x8: +PET_00)Attribute) *(e5: +BE_01 (x1)Theme (x9: +FRIENDLY_00)Attribute) </pre>
DESCRIPTION:	a member of the genus Canis (probably descended from the common wolf) that has been domesticated by man since prehistoric times; occurs in many breeds; "the dog barked all night"

Figure 5: Meaning postulates of the concept +DOG_00

As we can see in Figure 5 above, the meaning postulates of the concept +DOG_00 consist of the following predications encoded in the COREL language (Periñán-Pascual and Mairal 2010):

1. +(e1: +BE_00 (x1: +DOG_00)Theme (x2: +MAMMAL_00)Referent)
2. *(e2: +BE_01 (x1)Theme (x3: +TAME_00)Attribute)
3. *(e3: +EAT_00 (x1)Agent (x4: +MEAT_00 ^ +BONE_00)Theme (x5)Location(x6)Origin (x7)Goal)
4. *(e4: +BE_01 (x1)Theme (x8: +PET_00)Attribute)
5. *(e5: +BE_01 (x1)Theme (x9: +FRIENDLY_00)Attribute)

If we reword the previous predications in natural language, we have the following correspondences:

1. A dog is always a mammal.
2. A typical dog is tame, but it could not be the case (we can find wild dogs).

3. A typical dog eats meat or bones, but it can not be the case (we can find dogs who are fed on dog food).
4. A typical dog is a pet, but not always.
5. A typical dog is friendly, but not always.

Finally, in FunGramKB ontology we come across subconcepts, which are a refinement of the possible candidates, called selectional preferences, in the thematic frame of an already existing basic or terminal concept. They represent those cases in which the conceptual restriction or specification takes place exclusively in one or all of the participants of the thematic frame of a basic or terminal concept, without varying its meaning postulate. They are preceded by a hyphen (-). An example would be -BARK. Figure 6 below shows the FunGramKB editor interface with the predications that define barking as a specification of the sound that dogs make with their mouth. In other words, a subconcept is a specification in the thematic frame of another conceptual unit. In this case, the participant involved in the event of making a sound is further specified by stating that the creature who emits this kind of sound with his mouth is a dog and no other kind of animal.

The screenshot shows the FunGramKB Editor interface. The main window is titled "FunGramKB Editor" and "Ontology Name: Core". On the left, a tree view shows 547 events, with the subconcept -BARK selected. The right pane displays the "Conceptual Information" for -BARK, which is a subconcept of +SOUND_01. The information is as follows:

CONCEPT:	\$SOUND_00 [-BARK] <input checked="" type="checkbox"/>
SUPERORDINATE(S):	+SOUND_01
THEMATIC FRAME:	(x1: +DOG_00)Theme (x2: +SOUND_00)Referent
MEANING POSTULATE:	+(e1: +SOUND_01 (x1)Theme (x2)Referent (f1)Beneficiary (f2: +MOUTH_00)Instrument)
DESCRIPTION:	Utter a sound through the mouth.

At the bottom, there are three columns for translation: English, Spanish, and Italian. The English column lists "bark", "growl", and "snarl". The Spanish column lists "gruñir" and "ladrar". The Italian column is empty. Each column has a "Y", "N", and "X" button for selection.

Figure 6: Predications of the subconcept -BARK

3.3 Inheritance and inference relations

As stated in Pérez Cabello de Alba (2017), in FunGramKB, inheritance relations give account of typification, namely, the “is a” relation, in a way that the first predication of every concept always contains the relation of the concept with its immediate father. Taxonomy, i. e. “there are several types of” relation, is also accounted for in terms of inheritance, and all concepts which hold a relationship of sisterhood will be under the same father concept, so they will then share the x2

(second) component of their first strict predication. It is important to point out that the top-down organization of concepts is accounted for in FunGramKB in a way that the same definition is inherited by all the entities belonging to a class. Thus, the information in the rubric “Description” for the concept +MAMMAL_00, i.e. “any warm-blooded vertebrate, having the skin more or less covered with hair, nourishing the young with milk, and, with the exception of the egg-laying monotremes, giving birth to live young” appears uniformly allocated to all its hyponymic concepts existent in the conceptual hierarchy, such as +BEAR_00, +CAT_00, +DOG_00, +HORSE_00, to name just a few examples.

On the other hand, through inference relations we obtain the features that concepts share with other entities of the ontology to which they are not related through an inheritance relation. The microknowing in FunGramKB (Periñán and Arcas, 2005) gives us the extended meaning postulate, and puts in connection the basic concepts which appear in the meaning postulates in the ontology. Let us take, for example, the cases of +DOG_00 in Figure X and –BARK in Figure 7 below.

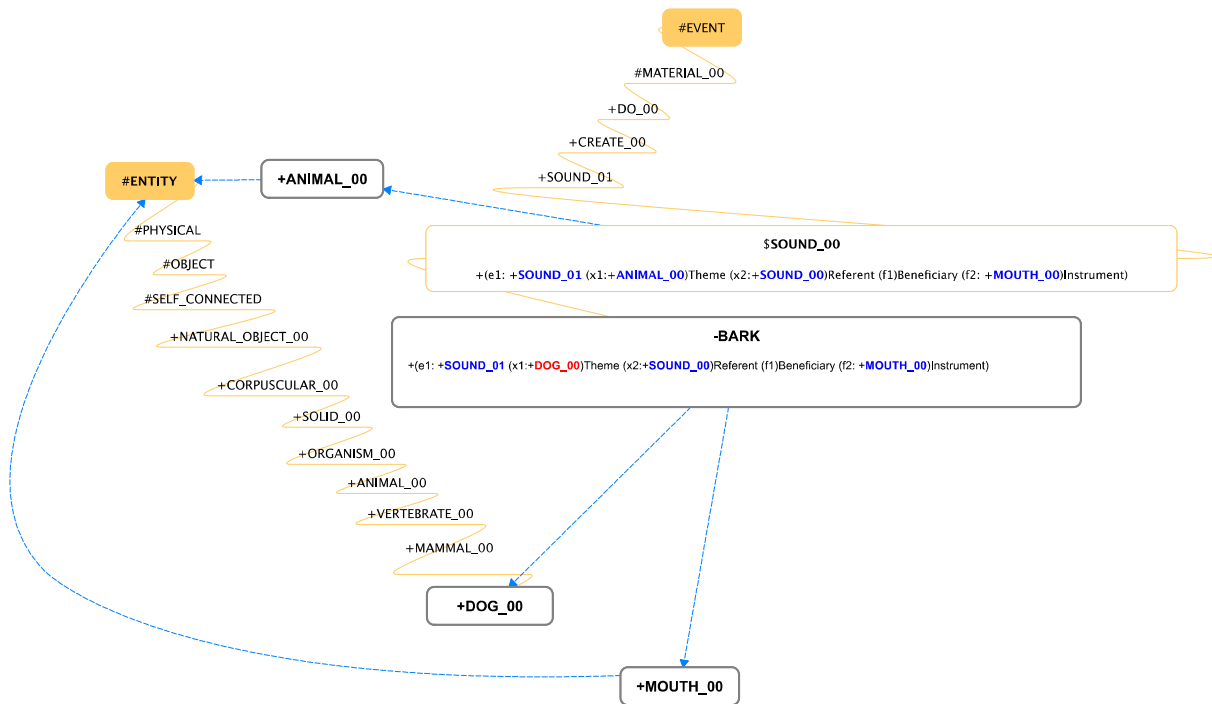


Figure 7: Some of the inference relations of the concept +DOG_00

In Figure 7 we have two root metaconcepts, one of the type #ENTITY and another one of the type #EVENT. There is a hierarchical organization within each metaconcept where inheritance relations are established. If we go to the subconcept –BARK, we see that relations with other concepts are established through the basic concepts that appear in its conceptual definition. In this way, we see that there is a relation with the entities +DOG_00 and +MOUTH_00. In this way, concepts in the ontology are interconnected and this fact allows us to replicate the way in which semantic memory works.

Thus, both types of relations - inheritance and inference - allow us to create complex and rich networks where the concepts access the information by their onomasiological situation through inheritance relations with their hypernyms, and by inference relation or by the predications they encode themselves. It is this kind of rich semantic network that will allow us to locate the breakdown in cases of semantic memory loss, as we will show in the next section.

4. Location of the damage along the conceptual routes in semantic memory loss

Ever since Warrington & Shallice's (1984) work, many studies, whether these build upon the neural structure principle or the correlated structure principle, corroborate the dichotomy between living and non-living things in semantic memory loss (see also Basso, Capitani & Laiacona 1988). More recent studies like Zannino et al. (2006) confirm the existence of a category specific semantic loss in Alzheimer's patients who have more difficulty in the processing of living thing categories than non-living ones. In addition, there seems to be a double dissociation, since there are patients who have problems with living things but not with non-living things, while there are other patients that show the reverse pattern (Hillis & Caramazza 1995). The picture gets more complicated when we look at patients that do not fit into either of these patterns. For example, some patients have problems with living things but have, nevertheless, a normal performance with categories that refer to body parts, which are clearly part of living things (cf. Warrington & Shallice 1984; Silveri & Gainotti 1988; Siri et al. 2003). Yet another issue that gets things even more complicated is the fact that some patients' performance does not fit into either dichotomy. A case in point is described in Siri et al. (2003): the patient had problems with fruits, vegetables, musical instruments and birds, while s/he preserved relatively good performance with animals, parts of the human body and furniture. Some other categories like tools, clothing and vehicles, are maintained but not consistently. This case study resorts to several kinds of tasks like picture and category naming and measures other cognitive abilities of the patient.

By means of a naming task for different categories, Peraita & Grasso (2010) aimed to study differential category loss in Spanish speakers who suffer from Alzheimer. They used a model for semantic memory based on features and componential analysis, distinguishing between features that make up categories and the relations between these features and the categories they belong to. So, every category is composed of several features that are related with the concept by several kinds of relations such as taxonomic (X is a kind of Y), perceptual (X is a property of Y), or functional (X is for Y-ing). Note that this model resembles the Functional Lexematic Model (Martín Mingorance 1998), which is one of the foundations upon which the linguistic module of FunGramKB builds, together with Putstějovský's (1991) qualia relations. Peraita & Grasso demonstrate with their empirical data that not only can a differential loss between living and non-living things be defined, but also across several kinds of features according to their relation to the category. That is, taxonomic features are the most complicated features for these patients, while the easiest ones are part-whole features. However, the latter features are also the ones that are more rapidly lost, whereas functional features are the ones that are best preserved along the illness.

The models based on the correlated structure principle predict that the loss of one category will affect all the concepts that depend on that category. For example, if a patient has lost the concept 'animal', then all the categories that depend upon 'animal' will be lost too, such as 'dog' and 'horse'. However, this is not the case for Siri et al.'s (2003) patient, among others, who presented problems with living things in general (fruits, vegetables, birds) but he had a relatively preserved performance with certain living things like animals other than birds and human body parts. He had a spared performance with some non-living things like furniture but not with others like tools, kitchen items, toys and vehicles, and musical instruments. This pattern defies the models based on the neural structure principle too since these concepts do not share modality knowledge nor do they belong to any of Santos & Caramazza's (2002) evolutionary-based domains. So, this case and others that we will review below, pose an important challenge to these theories.

Warrington & Shallice found a very specific pattern of semantic memory loss in four of their (1984) study patients: they had problems with living things categories like flowers, fruits, trees, vegetables and animals, whereas they maintained a good performance with non-living things categories like clothing, furniture, kitchen utensils, and vehicles. They assumed then that all categories that depended upon the superordinate living things category were damaged: animals (dogs, horses, etc.), people, and plants (flowers, fruits, vegetables, etc.). This accounted for this poor performance on categories like flowers, fruits, trees, vegetables and animals, all living things, in contrast to the normal performance on other categories like clothing, furniture, kitchen utensils and vehicles, all non-living things. The prediction is, thus, that the patients with this pattern of semantic memory loss, i.e. problems with living things but who perform well with non-living things, will have problems with all living thing categories like for example, monkey, banana, lion, and priest; while they will have a good performance with all non-living things like, for example, table, vase, rock, and train.

While some studies like Peraita & Grasso (2010) and Zannino et al. (2006) have fulfilled this prediction and corroborated Warrington and Shallice's results, i.e. problems with living thing categories and no problems with non-living thing categories, many others have provided empirical data showing that this is not always accurate and the prediction that all living thing categories are damaged while all non-living thing categories are maintained is not always the case. For example, J.B. was a patient described by Warrington & Shallice (1984) whose pattern of semantic memory loss was quite different from the pattern they found in their first four patients: he had problems with some non-living things (metals, clothes and precious stones) but not with others (furniture, vehicles and kitchen utensils); besides, he had problems with living things, as expected, but he maintained a good performance with body parts, which are part of living things. Other patients who have problems with living things but not with body parts have been presented by Silveri & Gainotti (1988) and Siri et al. (2003). Hart, Berdt & Caramazza (1985) presented the performance of M.D.'s, who had problems with some living things (fruits and vegetables), but surprisingly, he had no problems with animals. Caramazza & Shelton (1998) presented E.W., whose performance was compromised with some living things (animals) but not with other living things and non-living things. These results pose a problem not only for the original

hypothesis of Warrington & Shallice but also for the Sensory/Functional Theory, since the pattern of semantic memory loss is unrelated to the different modality-specific semantic subsystems that are resorted to. Finally, researchers like Siri et al. (2003) have provided empirical data from patients that are quite difficult to fit into any pattern of semantic loss: J.P. had problems with some living things like fruits, vegetables, and birds but not with others like animals and human body parts; besides he had problems with some non-living things like musical instruments but not with others like furniture; furthermore the performance varied depending on the experimental task J.P. had to face (category naming, name-picture matching, etc.).

We propose to use FunGramKB's conceptual chains defined by inheritance and inference relations, which will provide the foundation of a unitary explanation for the different semantic memory loss patterns shown by patients described by Warrington & Shallice (1984), Hart, Bendt & Caramazza (1985), Caramazza & Shelton (1998), and Siri et al. (2003). As seen in section 3, FunGramKB is a knowledge base that codifies different kinds of information: conceptual, lexical, morphological, grammatical, pragmatic, and even cultural and used-based information. The core part of the knowledge base is the ontology, which is a collection of encoded concepts organized in chains defined after inheritance relations. This way, the conceptual information has to be encoded only once, and then, it may be shared by different concepts by either inheritance relations – if the goal and target concepts are in the same chain – or by inference relations – if the goal and target concepts are not in the same chain. In what follows, we are going to show how FunGramKB's ontology can be used to help us define fine-grained conceptual routes, based upon inheritance and inference relations, along which the conceptual damage in different kinds of semantic loss can be located. Consequently, this will lay the ground for the characterization of different memory loss patterns in terms of how some conceptual routes are broken, or rather, where the break is located along such conceptual routes. So, we will show that FunGramKB's conceptual chains allow us to explain “canonical” cases like Warrington & Shallice's (1984), as well as other “non-canonical” ones like Siri et al.'s (2003) patient, without defining evolutionary-based domains, without resorting to modality-based knowledge, and correctly constraining the semantic loss patterns to be found. This will allow checking predicted loss patterns against empirical data from patients in future research.

We are going to use the conceptual chains of the ontology of FunGramKB defined after the inheritance relations among concepts, as discussed in section 3, and locate the break along such chains. Note that we are assuming without further argumentation that the conceptual organization in the brain equals, somehow, the conceptual organization in the FunGramKB ontology. We do so for the sake of simplicity: we just want to show that a linguistically rooted theory of conceptual organization can help us understand the empirical data found so far. Depending on the location of the break, a certain subset of categories will be affected. The higher in the ontology the break is, the more general the damage will be and the more categories will be lost. Figure 8 shows the conceptual chains for the most studied categories in the reviewed literature: categories like *dog*, *cat*, and *horse* are hyponyms of +ANIMAL_00; *tree*, *vegetables*, and *fruits* are hyponyms of

+PLANT_00, and non-living things like *furniture*, *clothing*, *tools*, and *vehicles* are all hyponyms of +SOLID_00.

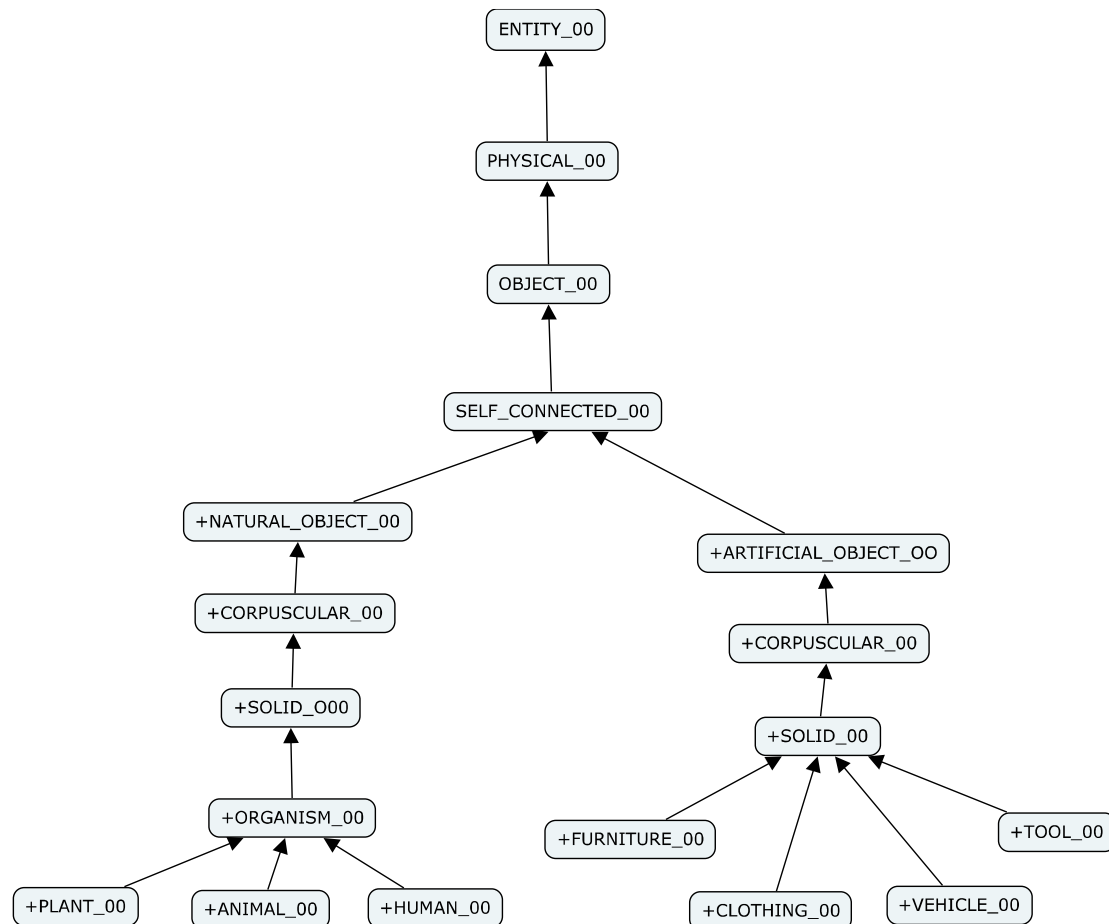


Figure 8: Conceptual chains for the most studied categories in the literature

The classical prediction is that patients who show problems with living things will show problems with all living things and no problems with any non-living thing. This pattern is easily accounted for if a break can be located in the chain at the level +ORGANISM_00. If so, all living things will be damaged, including plants (+PLANT_00), animals (+ANIMAL_00), and human beings (+HUMAN_00). Other concepts, more specifically, non-living things (e.g. +TABLE_00), will be unhampered because they do not depend on the basic concept +ORGANISM_00.

However, we have argued that this prediction of a perfect break between living and non-living things is not borne out in all the cases. Hart et al.'s (1985) M.D. patient had problems with some living things (fruits and vegetables) but not with animals. If the break was on +ORGANISM_00, animal categories would be affected. Empirical data thus support that idea that there is a break somewhere lower than +ORGANISM_00. One possibility is that there are two more local breaks on the +PLANT_00 level. This accounts for the problems with fruits and vegetables, both of them hyponyms of +PLANT_00, while preserving animal categories, hyponyms of +ANIMAL_00 and not dependent of +PLANT_00. The lower the break is along the conceptual chain, the more restricted the semantic memory loss is. Caramazza & Shelton's (1998) E.W. patient had a reverse semantic

memory loss pattern: he had problems with animals but not with other living things, as well as non-living things. They argued that these data pose a problem for the Sensory/Functional theory since all these concepts resort to the same modality-specific semantic subsystems, which would ensure that both categories (animals and plants) are either damaged or unhampered. If we use FunGramKB ontology, these two patterns can be derived without further machinery: while the break in M.D. is on the level of +PLANT_00, and hence he had problems with fruits and vegetables but not with animals, the break in E.W. is on the level of +ANIMAL_00, which accounts for the loss of animal categories but not of other living thing categories.

Things, however, are far more complicated as Warrington & Shallice's J.B and Siri et al.'s J.P. show: these patients had problems with living things but not with body parts, which are clearly related to living things since they are parts of them. This seems unexpected unless we look at the location of the category +BODY_PART_00 in FunGramKB, which is represented in Figure 9:

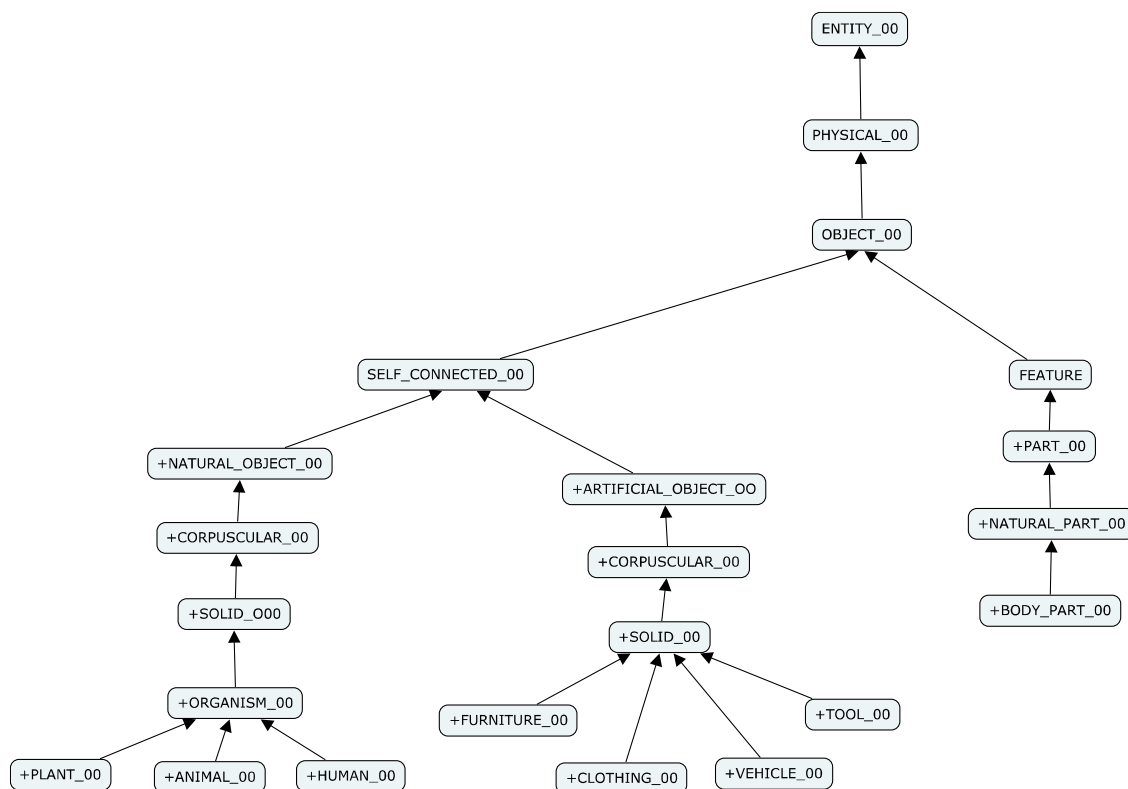


Figure 9: Conceptual chain for body parts

Concepts like ‘eye’, ‘ear’, ‘mouth’, etc., are hyponyms of +BODY_PART_00, which is a hyponym of the categories +NATURAL_PART_00, +PART_00, #FEATURE_00 and #OBJECT_00. This means that +BODY_PART does not depend upon +HUMAN_00 or +ANIMAL_00, which are quite lower in the chain, although they do contain this information in their meaning postulates. For example, one of the predications of +EYE_00 is *(e3: +SEE_00 (x4: +HUMAN_00 ^ +ANIMAL_00)Theme (x5)Referent (f2: x1)Instrument), which refers to +HUMAN_00. The prediction is, thus, that patients that have problems with

animals (and therefore a break on the level of +ANIMAL_00), humans (and so a break on the level of +HUMAN_00), and with all living things (and accordingly a break on the level of +ORGANISM_00) will not have problems, in principle, with body parts, because they depend on other categories higher in the chain. In other words, body parts follow a completely different conceptual route than animals, humans, and all the other living things. Thus, the empirical data from both J.B. and J.P. are accounted for and, as a matter of fact, expected from the configuration of the conceptual chains in FunGramKB.

Then, why are there patients that have problems with body parts? In order to give a proper account of this, let us look at the predications involved in the concept +BODY_PART_00 and the related concept +BODY_00, which we show in Figure 10:

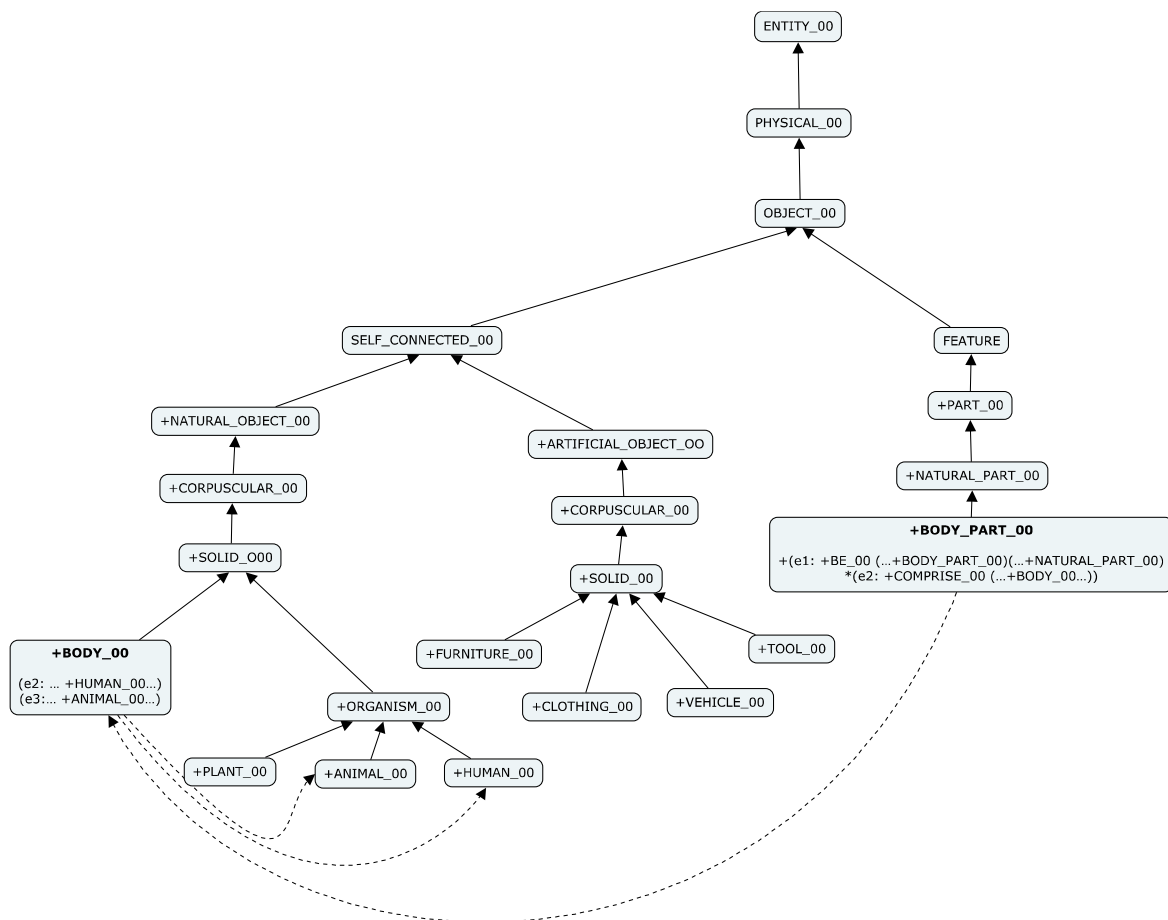


Figure 10: Predications of +BODY_PART_00 and +BODY_00

The meaning postulates of +BODY-PART_00 are made up of the following two predications:

- +(e1: +BE_00 (x1: +BODY_PART_00)Theme (x2: +NATURAL_PART_00) Referent)
- *(e2: +COMPRISE_00 (x3: +BODY_00)Theme (x1)Referent)

We see that +BODY_PART_00 comprises the concept +BODY_00 (first predication above), which is a hyponym of +SOLID_00 and at the same level as +ORGANISM_00. This implies that even a break in +ORGANISM_00 would not

affect +BODY_00, which makes both +BODY_00 and +BODY_PART_00 quite robust categories for semantic memory loss. If we look at the predications of +BODY_00 we find links to the concepts +ANIMAL_00 and +HUMAN_00, which are hyponyms of +ORGANISM_00. Note that the links to these conceptual units are obtained via inference relations rather than inheritance relations. This means that a patient that has lost ‘animal’ and ‘human’ categories has not lost these categories themselves but the access to them through the conceptual chains that are defined after inheritance relations. Probably, the concepts that belong to these categories are, to a certain extent, still available through other ways, more specifically, through inference relations. Nonetheless, if these relations are damaged, concepts belonging to +ANIMAL_00 or +HUMAN_00 will be completely inaccessible. Hence, the loss of body part categories may not indicate a break in the conceptual chain, which is defined after inheritance relations. For example, it may indicate the presence of damage either to the inference relations established in the network or to the patient’s ability to establish such relations. This is a qualitatively different kind of damage to semantic memory, whose consequences are more devastating: if inheritance relations are broken, then a subset of concepts are damaged and, then, inaccessible through the conceptual route. These concepts can, nevertheless, be accessed through inference relations from other concepts. If, on the other hand, the inference relations are broken, then the concepts affected by the break in the conceptual chain will be completely inaccessible. Therefore, the body part categories can be used in a diagnostic process to check whether inference relations are impaired or not: if not, the patient will probably have problems only with inheritance relations and then we should establish the location of the break or breaks along the conceptual chain. If, on the contrary, the patient has problems with body part categories, this indicates that the damage is bigger and qualitatively different, which may indicate that its evolution is different from the evolution found when the damage involves broken inheritance chains.

5. Conclusions and lines for further research

We have used FunGramKB ontology to explain different patterns of semantic memory loss, which were previously unaccounted for in a unified way. This ontology allows two kinds of relations: inheritance and inference relations. The first type defines conceptual chains along which one or more breaks can be located, which triggers different semantic memory loss patterns.

We have seen that besides breaks along the conceptual chain, i.e. damage to certain inheritance relations, also the inference relations can be hampered, which makes the damage bigger and qualitatively different. Categories of body parts indicate whether there is loss of this latter type of relation in the semantic memory.

It is our hope that this work lays the ground for future work that relates different semantic memory loss patterns to breaks at different locations along the conceptual routes and damage to inference relations, which will all together allow a finer-grained pattern with many predictions. These patterns, in turn, will be related with different types of dementia and brain damage, so that they become markers for non-invasive diagnostic of such conditions.

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