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Naturalized Epistemology for Autonomous Systems

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This paper explores issues concerning naturalized epistemology and the use of isomorphism criteria in analysis and construction of autonomous systems. A system, from an ontological context, is seen as a set of objects and relations; the demand for explicit definition is supplied by ontologies, using as is our case, a cognitive inspired conceptualization.

On the other hand, a naturalized epistemic account is proposed following the constructivist paradigm. We begin defining the basis level, where irreducible extralogical–phenomenic primitives are set out. Upon the simple primitives of basis level, further and more complex levels are defined, through subsumption process, permitting to correlate different conceptual levels in terms of their respective primitives.

Following this constructivist praxis, we expect to obtain a shaped set of isomorphisms between the *system form*, that is, the epistemic part of the system, and a range of perceived objects and events of the environment where the system is placed.

1 Introduction

In the present work, we try to give sound answers to the next two questions: primo *It makes sense to ask how knowledge is acquired and managed by humans in order to build*

autonomous system ? and secondo *Should autonomous systems, such as mobile robots, learn and manage conceptual systems in unsupervised way?*

In the analytic philosophy tradition, the only way concepts could be shared by different people was because they are disembodied and abstract. The meaning, according to this theory, would be a set of abstract relationships between words and aspects of an objective, mind independent and external world. This extreme externalist comes from the erroneous identification of thought with language; an analysis of language can not explain by itself the thought, the former is an approximative vehicle to express the later. We rightly consider that language and thought are two different ontological categories, so and we can not subsume one into the other.

In the theory of meaning we are proposing, the meaning of concepts come through embodied experience. Conversely to externalism and formalism approaches, the words, do not pick up existing entities in an objective world but express concepts which resides in the mind. The meaning of the words is obtained via embodiment. The traditional sharp distinction among perception and conceptualization must be undercut. Recent experiments have shown that same neural mechanisms are involved in either perception and conceptualization(10). Neurons occupied in responding sensory stimuli(visual, auditory...), not only process sensorial information but are also involved in motor control. The hypothesis we are setting out is inspired in cognitive linguistics, computational models(11), and brain studies(12). It assumes that pre motor and parietal brain areas form a functional unity that achieve both control action and representation. Therefore the meaning of the words would be inescapably related with action and perception.

Recent neurological experiments have reach the conclusion that part of conceptual system in the human mind arise from exercising motor schemas, roughly, action schemas precede conceptual thought. Our claim is that we can not set aside this empirical assertion. If neural mechanisms are involved in perception and action, and bodily movement play a central role in conceptualization, is worth building biologically plausible ontologies for autonomous systems(henceforth AS). In the past, robots with a behavior predominantly reactive could evolve in a domestic environment without crashing, executing successfully routines like *avoid_obstacles* or *keep_on_straight*. But to affirm that the machine posses the concepts *obstacle* or *straight* is totally illusory, in fact is the programmer, and only him, who has the concepts.

Only AS that count on his own conceptual system can evolve in new environments and have the capacity of learning under which category fall not pre programmed instances found on his way.

This paper is structured as follows, we begin by giving a definition of concept, in section III we set up he basis of the classical theory of concepts which consists in a list of necessary and sufficient conditions to be satisfied. Section IV establishes the basis of a naturalized theory of concepts, in the light of this, prototype theory

and a naturalized ontology based on embodiment and simulation are sketched. Section V proposes DOLCE as the cognitive inspired ontology that provides the theoretical framework of our naturalized theory of concepts. In the last section we discuss hypothetical primitives for linguistic, sub linguistic, and neural domains respectively. Further development in AS are in progress in order to validate the primitives here related.

2 What is a concept and what are they good for in Autonomous Systems?

Concepts are the most foundamental constructs in theory of mind. Traditionally the study of concepts has been focused on lexical concepts, anyhow is worth remarking that lexical concepts are just one type of concept, others such as images are present in our conceptual systems too.

The linguistic approach of concepts is motivated by the easy accessibility and apprehension of words; we know lexemes denote concepts but obviously this is insufficient to build complete theory of meaning. Neural correlates or social cultural aspects must be incorporated to our theories of concepts. [1]

We define concepts as embodied mental representations, we can use and share concepts by means of words, but the causal relation,that is, where and how concepts arise is a biological based question too and not only a linguistic affair. There is not to say that concepts are triggered by neural structures, the deterministic explanation of the how and where this is achieved is still to be figured out, but evidences suggest that perception and action circuits, are both the neural basis of word meaning (2). So, we might conclude that concepts are in part caused by sensomotor system in our brain.

To clarify the above paragraph, we pass to comment Frege's semantic theory which is opposed to our claim that concepts are neural structures that make use of the senso motor system of our brain. In Frege's sense theory "two people are not prevented from grasping the same sense, but they can't have the same idea". Frege is going to far, from the fact that an olive tree is objective, and the mental representation OLIVE TREE is subjective, we can not infer that two different people are unable to share the same concept or mental representation. He is confounding mental representation (in his words "the very same representation") with the the very same neural correlate. Mental representation are subjective because belong to the thinking subject, but this does not preclude being shareable, a group of people can have the same concept even though the concepts come from different brains.

The way the brain conceptualizes is multimodal, roughly, conceptual representation arises not only from cortex areas related with abstract thinking but also from

[1] A sort of mystic or Adamic concept of language as an agent that affects matter is refer in (1)

senso motor areas in the brain in charge of transmit movement signal to the muscles. It is through action and perception the way we construct abstract representation of referents(external objects in the world).

3 Classical Theory of Concepts

The theory presented in this section has been predominant in theory of mind until the seventies, moment in which psychological evidences began to reveal her weakness.

Classical Theory(henceforth CT) states that concepts are mental structures consisting in a set of sufficient and necessary conditions to be satisfied, formally *an instance i fall under a concept C iff* $\forall feature f \epsilon C$ *f(i) is true*.

Let us see an example, in accordance with the compositional semantics principle that this theory follows, the concept WIDOW is defined in terms of the joint of the simpler concepts WOMAN, ADULT, WAS_MARRIED, HOUSEBAND_DIED. so, an entity e falls under the concept WIDOW iff the next predicate is satisfied: $WOMAN(e) \wedge ADULT(e) \wedge WAS\_MARRIED(e) \wedge HOUSEBAND\_DIED(e)$.

3.1 Criticism to Classical Theory

The strength of this theory becomes her weakness from a naturalized point of view. The notion of membership to a concept is clear cut and discrete, that is to say, we can conclude that an object falls under a concept by means of checking each one of the necessary and sufficient conditions. Proceeding in this fashion we are assuming implicitly that every member of a concept belongs to it at the same degree. But psychological experiments have point out that not all the instances have equal footing in the concept they belong to, for example, an apple is categorized as a fruit more efficiently than a pomegranate. We can conclude that CT is a not natural model for conceptualization.

Another criticism posed to this view is her excessively descriptivist bias. In practice, we do not need to elaborate long lists of necessary and sufficient conditions to be satisfied in order to conclude an object belongs or not to a concept, rather categorization seems to be done in a more natural, faster and efficient way, using extensional approach(and not only intensional used in CT), which consists in contrasting the object to be included into a concept with other other members of the same concept. Classical Theory assumes wrongly that concepts have deterministic extensions, omitting that conceptual boundaries used to be fuzzy, in fact indeterminacies can be easily found: Is a computer an electrical appliance?. Is a coffin a furniture?.

To finish this section we point out the famous holistic claim of W.V.O. Quine(3).

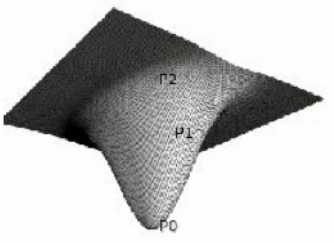

Figure 1: Gaussian function that represents membership function in PT

An individual statement is never confirmed in isolation but instantiated in a global theory, indeed statements that in an instant t is true, in a successive instant can be false. An apparent concern with the last criticism is the next: an account for temporality and cultural changes must be contemplated. Concepts like MARRIAGE or WEAPON have being modified in our conceptual systems in the last times, actually in some countries people of the same sex can get married, and since 1945 nuclear bomb is a WEAPON.

4 Naturalized Theory of Concepts

4.1 Prototype Theory

Classical Theory(CT) and Prototype Theory(PT) follow the principle of similarity: an object falls under a concept if we can determine that the object is sufficiently similar to the other category members. [2] The similarity property in CT is expressed in terms of formal rules which axiomatize all the sufficient and necessary requirements that an object must verify to be considered as member of the category. Conversely PT follows the Wittgenstein's argument: formal criteria are neither logical nor psychological necessity.

PT acknowledges that concepts often describe a *family resemblance space*, as Wittgenstein pointed out with the concept GAME, there is not an unique common list of properties that games must satisfy to be considered members of GAME. It is important to note that PT do not negate that different items inside a concept might share a similarity law, but rather that similarity function is statistical and continuous and not discrete and digital as CT asserts.

In conclusion, the concept of membership of an item to a concept is degreed and the properties that define the concept have different weights and describe a similarity space area with fuzziness boundaries concept.

As is shown in figure 1 p0 is the most essential property is a local minimum,

[2] category and concept are used here indistintely for a more exended study see (4)

therefore an item accomplishing p0 would be a more representative member of concept C than an item that verify only p1 or p2. It is worth noting that when we say essential properties we are not claiming that things have essences. It happens that when we represent things we do it as if they had essence; this could be explainable in terms of evolution theory: essential properties could have been the most efficient representational mechanism for survival.

Before passing to the criticism of this theory, we want to remark that in PT, concepts encode properties following similarity principle as CT does. The difference resides in the fuzziness of the membership. In CT the instances are or are not member of a concept without any distinction of degree, while in PT the items inside a category tend to posses the properties, existing a margin for being a better or worse category member.

4.2 Criticism to Prototype Theory

We start this section by a remark that is not a critic or a weakness. (6)Experiments have revealed that people tend to think, even for abstract mathematical concepts like EVEN, that some members of the class are best representative than others, for example 8 is considered as a better representative of concept EVEN than 48. This constitutes another evidence of the fact that human categorization is based on prototypes but is logically absurd. One of the aim of this paper is to set the basis of a theory of Concept and his application in AS. In spirit of this, we want to address the next two questions: for a robot seems logical that either 8 and 48 were EVEN numbers at the same degree, just because both are divisible by 2, so:

Can we build robots that categorize as human do? and if this is the case *Is plausible to expect a more intelligent behavior of the robot with this human inspired categorization?*

Relativity in concept membership can drive to contradictory or unsound situations; due to the statistical bias of PT, it could happen that one entity, satisfying some properties of a concept, could be considered as member of the concept without being it. To avoid it, essential attributes must be provided but without revert into classical theory. We explain this with the next example, a BAT could be considered a BIRD; it flies, has wings, is small etc. It satisfies a number of properties that BIRDS do, but the point is, these properties are superficials. We know a BAT is not a BIRD, even though it accomplishes superficial properties of BIRDS, because does not verify the deep property DNA, which establishes that a BAT is a not a BIRD but RODENT.

Accordingly with the distinction between essential and superficial properties in concepts (L.Komatsu(7))has proposed a similarity space for concepts called PLACEHOLDER, where it would reside the essential properties, that is, the attributes to be necessarily accomplished by any entity belonging to a concept. Two remarks easily arise: the first, PT using PLACEHOLDER space suppose in some sort a come back

to the CT because imposes properties to be compulsory satisfied, and the second, there is no any procedure to determine the essential properties of a given concept, and besides, in case we could find an identifiable list of essential properties, they would not remain unchanged over the time.

Our claim is that a distinction must be made between natural and nominal concepts[3], the former would had essential properties to be satisfied, for example in vegetarian or animal species the DNA and the later would be present in concepts that lack of essential attributes; examples are easy to find in concepts concerning social conventions, like king, pharmacist or housewife. Another important difficulty with PT is the compositionality problem, as Fodor has noticed some complex concepts have not prototypes and when they have, they are not function of its constituents. This is because the intersection operator for concepts does not work as does for maths in the set theory. In fact, a good instance of A and B could be a poor instance of A. Thus, for example, a good representative of the complex concept PET FISH is a golden, tiny fish inside a water tank, but on the other hand it is a bad representative of the constituent concept FISH which used to be thought in terms of medium sized and gray and hardly golden or tiny.

As it will be detailed later, an attempt to place PT inside an epistemic framework that permits to set out the relationships among either attributes that form a concept and the different concepts, can not be neglected anymore in the task of building a theory of concepts that could drive us to build AS provided with deliberative reasoning.

5 Foundational Ontology in naturalized conceptual systems

CT and PT treat categorization as a function of similarity, an item is placed in a category if is similar enough to the other category members, checking to that end the accomplishment of a set of properties. An overcome of this approach is here proposed. Categorization is unlikely only based on judgements of strict similarity or typicality, rather concepts must be placed in the framework of a conceptual system, it is quite needless to say that individual concepts can not be understood isolated but in terms of relations with other concepts, inside a formal theory(8). Besides to differentiate among ”essentials” and ”accidentals” properties is necessary to build a naturalized theory of concepts. Accordingly, we need to place the concepts in a systematic way, forming set of believes projecting natural causality(9). The resultant network will be an ontology formed by abstract categories like endurant, physical object, quality etc. A more detailed account of this ontology is given in section V.B.

[3]We are using Fodor terminology but in a completely different fashion

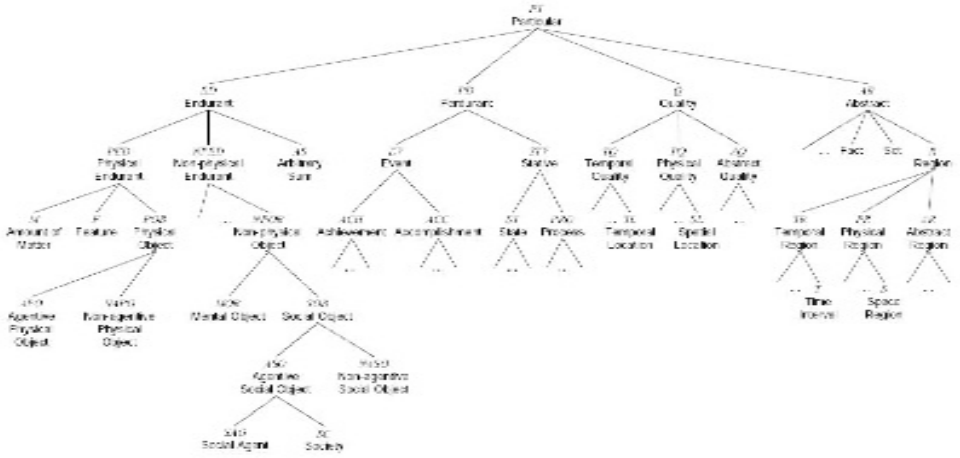

Figure 2: DOLCE ontology

5.1 DOLCE

DOLCE(Descriptive Ontology for Linguistic Cognitive Engineering) is a foundational ontology originally created for semantic web purposes (WonderWeb)(13). DOLCE as an upper level ontology has been successfully applied in different domains like biomedicine, agriculture, manufacturing (14) or social organizations(15). It goes without saying that an ontology cannot be a mere classification that express facts and rules, written in a more or less formal language, but a toolset that aims to catch entities in order to place them in conceptual categories, built with cognitive bias and forming a conceptually sound framework.

We want to emphasize that categorization is an inescapable consequence of our biological makeup, we cannot choose whether categorize or not, we just do it, even an amoeba categorizes things it encounters into food or not food.(4). Using DOLCE we are assuming the claim that categories captured by this ontology are not related to intrinsic nature of the world (if there existed such a thing) but to cognitive items based on human perception, cultural prints an social conventions. DOLCE taxonomy is shown the figure 2, of the four basic categories defined in DOLCE: Endurant, Perdurant, Quality and Abstract, for our purposes we do not consider the Abstract category.

- Endurant: entities that are in time
- Perdurant: events, happen in time
- Quality: are the basic entities we can perceive or measure

The main axiomatic assumption that DOLCE establishes is concerned with the

distinction between endurant and perdurant categories, which is based on *participation*. Endurants are objects that are in time by *participating* in perdurants, for example, Gordon Brown is an endurant that participates in a perdurant, his own life.

We claim that DOLCE is conceptually sound and well suited to be used as a conceptual framework in AS, thanks to the the next commitments:

- DOLCE is descriptivist, it aims at capturing categories underlying natural language and common sense
- DOLCE is no reductionist, allows different entities to be co-located in same space time, conversely to reductionist claim that one space-time location can contain only one object
- DOLCE can model entities changes along the time, endurants model 3D objects and perdurants capture entities that extend in space and time, also called 4D objects

6 The Primitives in a Naturalized Theory of Concepts

The necessity of count on a set of lexical primitives, that combinated permit to build complex sentences, is almost shared by everyone. A major exception is J.Fodor(16) who considers the concepts as monodic, that is, since concepts have no parts in which can be separated, speak about lexical primitives would be purely chimeric. Fodor claims that all the concepts are innate, and he arrives to this conclusion because as he points out, we can not explain the meaning of a word just by means of mere combination of other word, circular and ungrounded interpretation of meaning is inevitably obtained. But even assuming the correctness of this claim we do not see how concepts like brush, gear or tap can be innate as Fodor affirms.

The present paper stays far from the innateness or the irrectuctibility of concepts assumed by Fodor, rather the concepts reflect structures that can be decomposed into more simple forms, is not hard to find in english language suffixes or words with similar roots (hopeful, useless, homeopathic...). The problem of primitives must be reconsidered in the light of a more complete and multidisciplinary fashion. If we pretend to elucidate the existing correlation between words and the neural configurations in the brain that constitutes the cellular substrate of the mental images evoked by the words, a theory that describes either which are the primitives and the way the are linked among the different levels, from lexical to neural, must be constructed.

We now proceed to explain the three kind of primitives that should exist in a naturalized theory of concept. We are hopeless that further works permit to obtain a formal theory of the primitives here briefly sketched.

6.1 Linguistic Primitives

We begin exploring the primitives at the most external level of cognition, the linguistic. A.Goldberg(17) based on Saussure's works define constructions as the basic unit of language representation that serve to link the form (phonological schemas) with the meaning (conceptual schemas). Constructions, called lexical units, subscribes the Gestalt Theory by which the language comprehension is inherently holistic, that is, it does not exist any compositional function that permits to get the whole meaning of an expression by the analysis of its parts.

Constructions are composed by a pair of elements called form and meaning $C=\langle form, meaning\rangle$, the former is the lexical expression in some of his variants (phonological, etymological...) and the later is a conceptual schema. Each construction has two components always present, *form* and *meaning*, and besides a set of optional components to be declared depending on the construction, for example when the construction inherits constraints from other one, *subcase* component is declared. Now it is important to notice that *form* is not a fixed word but a cluster of words that permit to deal with inflected forms(run,ran), multi word expression(run off, run after) and polysemy (telly,television) and that *meaning* may vary its structure depending on the complexity of the meaning related, we will see this more clear with the example that closes this section.

It follows, therefore, that a word is understood by means of an structured scenario that functions as the mental image necessary to ground the meaning of the construction's *form*, accordingly lexical items draw on rich conceptual structures. The theory we are proposing states that language understanting imply the activation of perceptual and motor schemas which obviously are physically placed in the neural substrate. Here arises a difficulty; words are discrete but the perceptual motor schemas evoked the words are continuous, dynamic and modal.

We propose to figure out this gap provide a theory with two main steps, analysis and simulation. Thus, given an utterance, the analysis process determine the set of constructions that are evoked by the words of the utterance and the resulting constructions of this step serve as the semantic specification, necessary to trigger the second step, the simulation process, which consists in the execution of embodied conceptual structures. Recall simulation is an automatic reactivation of sensory motor brain areas during the concept processing. [S.Narayanan](18) has built a graph-stochastic Petri net based formalism called x-schemas, used in simulation of planned actions in the physical world.

It is the propose of this article to give a brief outlook to the basis of a future naturalized theory of concepts to be implemented in an AS, further works are in process to aport empirical refutations of the assumpionts here sketch. The focus of the present work and of next articles is put on spatial prepositions and action verbs, thus constructions and schemas for that kind of concepts are being developed. [4] We

[4] A construction analyzer on a corpus of simple motion events has been developed in (19)

Table 1: Constructions evoked by utterance *Seneca walked*

construction	SENECA	**construction**	WALK
subcase:	PERSON	**subcase**	MOTION-ACTION
form:	”Seneca”	**form**	”walked”
concept:	Seneca	**concept**	Walk-Action

are aware that abstract domains expressions denote more complex or at least no so direct grounding with motor schemas, in those case our theory is hardly applicable.

The next example shows how are obtained the constructions from the utterance *Seneca walked*. Let us see the analysis phase that returns the constructions of Table 1. The simulation phase is out of the scope of this paper and not explained, for more details of simulation process see(20) :

1. For each word, determine the cluster which it belongs to
2. For each cluster, determine the construction that is evoked and if inherits form another construction
3. Establish the components of the constuction, the form is given by the word, and the meaning will be a conceptual schema

In our example, ”Seneca” is a proper name : the construction SENECA is a subcase of PERSON and link the form ”Seneca” to the referent Seneca(the famous stoic philosopher). Similarly ”walked” is a verb, evokes the construction WALKED which is a subcase of the more complex construction MOTION-ACTION. The grounded is got thanks to the link between the form ”walked” and the schema Walk-Action that captures perceptual and motor information about walking (for the complet realization of this schema (20)).

The construction may be map into DOLCE ontology, proceeding in this way we populate our ontology, initially composed of general concepts and relations, with instances of a particular domain. As a result we obtain the next two mappings:
SENECA - PERSON - APO - POB - PED - ED and
WALKED - MOTION-ACTION - ACC - EV - PED.

It reads as follows, SENECA is an instance of PERSON which is an instance of APO(Agentive Physical Object) which is an instance of POB(Physical Object) which is an instance of PED(Physical Endurant) which is an instance of ED(Endurant) and

WALKED is an instance of MOTION-ACTION which is an instance of ACC (Accomplishment), which is an instance of EV (event), which is an instance of PED (Perdurant).[5]

[5]Events are called achievements (ACH) if are atomic, otherwise, the action of walking, are accomplishments (ACC)

6.2 SubLinguistic-SupraCortical Primitives

Previuosly we have outlined the basis of DOLCE, a formal ontology that captures categories that lie behind human cognition. There is strong evidence that both perceptual and motor structures are necessary to understand the meaning of words. DOLCE is an ontology of particulars, of course universals do appear in an ontology of this sort. To keep notation minimal, the universals in our theory are called primitives of sublinguistic-supracortical level and configure the ontological categorization. Thanks to primitives, we count on categories that represent a *deep background* where the objects of a particular domain are instantiated.

In our naturalized theory of concepts nominalism is rejected, thus a symbol (/house/), refers to the external object (house) via the concept (HOUSE); otherwise the symbol would be directly connected with the referent and we would be assuming wrongly some sort of a priori or innatist relation between symbols(words) and referents(objects). It is erroneous to claim that ontology of particulars itself has meaning just because counts on symbols like /house/ /chair/ or /desk/. The way an agent, biological or not, dispose of meaningful symbols is sharing the ontological commitments suggested by the primitives we describe next. The primitives are the intuitive backbone properties of DOLCE ontology, and their justification is found in the own nature of perception and cognition. The primitives we relate below do not endorse a close set, rather we hope that further investigations aim to get new primitives and a better understanding of the already found.

Participation: This primitive motivates the distinction between endurants and perdurants, the endurants are things that are in time and participate in perdurants which are things that happen in time

Mereologic: The necessity of having parthood relations is given by mereologic primitive. An example of this is the sentence tail is a part of Emma the cat

Dependence: x depends on y iff, necessarily, y is present whenever x is present. For example a brain is dependent of its neurons

Unity: This primitive permits to distinguish among endurants without unity, called Amounts of matter(wood, water) from endurants with unity called Objects (a car, a rose)

Intentionality: Permits to distinct among agentive and non agentive categories. The former has intentionality, that is, has the capability of dealing with objects or states of the world and the later do not. Animals or robots are agentive objects and houses or pencils are non agentive objects.

6.3 Neural Primitives

In the two previous sections we have described the primitives for the levels linguistic and sublinguistic, now we pass to give some insight into neural level. In

this section we will set the basis of the model that correlates stimuli and neural configurations, details concerning physiological aspects of the brain are not provided, to that end neuro physiological support in terms of empirical experiments should be provided which is outside the scope of this article.

We take for granted that meaning is function of neural patterns activation, also called CNC (Consciousness Neural Correlates). Obviously to find the CNC or minimum neural configuration carrying meaning, is necessary to conceptualize perception forms, a complicated task mainly if we consider that most of the time we create and manipulate concepts we do it unconsciously. For example, everyday actions used to be routine and mechanical and seem to be executed by zombie agents which are mere executors without access to consciousness. Consciousness is only awarded of the result of the action and without direct access to the action process(21).

The literature is rich in theories of mental states based on linguistics that tend to obviate psychological and biological aspects in cognition. Clearly a naturalized theory of concepts has to assume the two next epistemic positions: first, language is not strictly necessary to can acquire and manage concepts and second If we try to explain conceptualization only in terms of words, we would be ignoring that every single concept we are using is caused by internal physical objects, the neurons. The motivation of the naturalized theory of concepts proposed here is to avoid circular explanation of meaning in terms of other meaning elements like words, and outline a model to determine the minimal functional unity that can carry content, what we are calling neural primitives.

But we have not still said nothing about how our theory endow the primitives with meanings. Neurons carry representational contents, we are claiming that exists an statistical dependence between the input received by a neuron and her output. Neuroscientists work constructing statistical models that figure out the neural response(output) given an external stimuli(input). Their experiments follow a third person approach: the input is deterministic actually are the objects shown to the subject nevertheless the output is probabilistic, is the potential field generated by neurons in response to presented stimuli(22). With this approach we obtain P(r|s), the function P that gets the distribution of the response r to a given stimuli s, in other words, we determine the way neurons spikes are generated, or in practical terms, how to cause an internal state in the brain from external stimuli.

In order to identify the neural primitives that carry meaning we need not only to know P(r|s), but also a model for P(s|r) or how stimuli are inferred from neural response. (Van de Walle et al.)(23) has demostrated that animals count on mechanisms that permit them to guess what stimuli in the environment is causally connected with a particular firing in the brain. If we dispose of P(r|s), and P(s|r), P(r,s) is easily obtained. P(r,s) is the probability that stimuli s and response r occur together, capturing all there is to know about probabilistic relation between r and s. Therefore an external object and its neural correlate would be linked by the high-

est statistical dependence. Immediately arises one question that we have to left to empirical investigation, which and how are the primitives for a concept once we know its neural correlate?.

It is helpful here to renember that subjective perception and reasoning are of course correlated with neural states, different neural states can evoke the same concept, but the opposite is false, two different concepts can not come from identical neural configuration(21). Therefore we conclude that neurons and content are not independent, but rather, meaning depends on neuron correlates, so counting on a precise model of stimuli and neural response, it would be possible to determine what and how the objects are perceived and categorized.

7 Conclusion and future works

We have proposed a naturalized theory of concepts, having as starting point the prototype theory. Categorization has been related to a cognitive inspired ontology, that permit to place the particular domain concepts following DOLCE axiomatization.

Nevertheless the theory described here is incomplete, further works should find empirical refutation of the hypothesis stated in the paper. In particular, special effort must be done in two directions: firstly how the basic neural primitives can ascribe meaning in order to get the causal/computational isomorphism between neural content and external objects and second define the necessary ontological commitments, in a naturalized ontology, that describe an epistemic framework of concepts and their relationships.

Future works concern with reducing the conceptual domain to the spatial one. The built an spatial ontology which will include either space prepositions(above, below, towards...) and action verbs(go back, come through) is previewed. Mapping the space ontology to DOLCE , determine the primitives at lingusitic and sublinguistic levels and the final implementation in a mobile robot is forseen.

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