Weighted Feature Typology Based on Semantic Feature Production Norms

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Abstract

Feature taxonomy proposed by sensory-functional theories to differentiate between domains (living or non-living things) received a number of critics: (a) the vagueness of the definition of attribute types; (b) the limitations of the dichotomous taxonomy; (c) the insufficiency of feature production variable to discriminate between domains. This paper aims to contribute to overcome these difficulties by proposing an analysis based on a complex taxonomy supported on empirical data obtained from Semantic Feature Production Norms in Spanish, considering features' frequency and order of production. Data was collected from a sample of 180 Spanish speaking healthy adults who produced defining features for 90 concrete concepts. The results show similarities between domains, in so far as to the primacy of superordinate attributes, and differences in the weight of the dynamic (functional and behavioral) and sensory features. This information is worthy to characterize the compositional structure of the features that constitute the semantic representation of concrete concepts.

Keywords: Semantic feature, semantic feature production norms, semantic domains, accessibility.

Tipologia de Atributos Ponderada Baseadas em Normas de Produção Atributos Semânticos

Resumo

A tipologia de atributos propostas pelas teorias sensório-funcionais para explicar as diferenças entre domínios (seres vivos e objetos inanimados) tem críticas mistas: (a) definição imprecisa do tipo de atributo; (b) limitações da taxonomia dicotômica; (c) insuficiência da variável frequência de produção para discriminar entre domínios. Este trabalho pretende contribuir para superar essas dificuldades, propondo uma taxonomia mais complexa e partindo de dados empíricos obtidos de Normas de Produção de Atributos Semânticos em Espanhol, considerando a frequência e ordem de produção dos atributos. O trabalho foi feito em uma amostra de 180 adultos saudáveis falantes de espanhol que emitiram

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atributos definidores para 90 conceitos concretos. Os resultados refletem semelhanças entre domínios na primazia de atributos superordenados e diferenças quanto ao peso dos atributos dinâmicos (funcionais e comportamentais) e sensoriais. Esta informação contribui para a caracterização da composição estrutural dos atributos que fazem a representação semântica de conceitos específicos.

Palavras-chave: Atributos semânticos, normas de produção de atributos semânticos, domínios semânticos, acessibilidade.

Tipología de Atributos Ponderada en Base a Normas de Producción de Atributos Semánticos

Resumen

La tipología de atributos propuestas por las teorías sensorio-funcionales para explicar las diferencias entre dominios (seres vivos y objetos inanimados) cuenta con diversas críticas: (a) imprecisa definición del tipo de atributo; (b) limitaciones de la taxonomía dicotómica; (c) insuficiencia de la variable frecuencia de producción para discriminar entre dominios. El presente trabajo pretende colaborar a la superación de estas dificultades proponiendo un análisis basado en una taxonomía compleja y partiendo de datos empíricos obtenidos a partir de Normas de Producción de Atributos Semánticos en Español, considerando la frecuencia y el orden de producción de los atributos. Se trabajó sobre una muestra de 180 adultos sanos hispanoparlantes que emitieron atributos definidores para 90 conceptos concretos. Los resultados reflejan similitudes entre los dominios por sobre la primacía de atributos supraordenados y diferencias en cuanto al peso de los atributos dinámicos (funcionales y comportamentales) y sensoriales. Esta información contribuye a la caracterización de la estructura composicional de los atributos que conforman la representación semántica de los conceptos concretos.

Palabras clave: Atributos semánticos, normas de producción de atributos semánticos, dominios semánticos, accesibilidad.

The question of the feature types that pre-dominate in semantic domain representations (living things vs. non-living things) is initially raised by sensory-functional models. These models suggest that conceptual knowledge is organized based on sensory modalities, and that for each semantic domain, one type of modality predominates (Farah & McClelland, 1991; Warrington & Shallice, 1984). Thus, it is traditionally held that the living-things domain is characterized by a preponderance of sensory-type features (for example, color and form), while the non-living domain is characterized by functional or associative features (for example, used for cutting or found in a workshop; Martínez-Cuitiño, 2007). Neuro correlates have even been suggested for each modality (Fargier et al., 2014).

Sensory-functional models have been criticized on various grounds, including the disparity of results and the methodology used (Capi-

tani, Laiacona, Mahon, & Caramazza, 2003; McRae & Cree, 2002; Peraita, 2006). In terms of the methodological limitations in the characterization of semantic domains, the criticisms can be grouped in three general categories: (a) Imprecision in defining sensorial and functional feature types; (b) Limitations of the dichotomic taxonomy; and (c) The mere production frequency of feature is inadequate for the purposes of discriminating domains, and therefore other qualities need to be considered to make this distinction.

Below we discuss the research that has been done along these three lines of criticism, and conclude with the present study's contributions to feature type descriptions that characterize semantic domains based on data obtained from the empirically derived Spanish Semantic Feature Production Norms (Vivas, Vivas, Comesaña, García Coni, & Vorano, 2016).

Imprecision in Defining Sensorial and Functional Feature Types

The criteria used to classify features as sensory or functional are not the same across studies on this subject. In McRae and Cree (2002), for instance, the researchers analyzed and tested differences between semantic domains according to the varying conceptions of the terms sensory and functional, and reported on the variations they observed. These authors point out that throughout the research on sensory-functional theories, the classification of features as sensory has varied from the exclusive inclusion of visual features (Farah & McClelland, 1991) to the inclusion of any type of sensory feature, be it texture, smell or feel (Caramazza & Shelton, 1998; Devlin et al., 1998). Further, Garrard, Lambon Ralph, Hodges and Patterson (2001) demonstrate that, although there is a relatively significant positive difference between sensory features for the living things domain compared to those for the non-living things domain, the difference in functional features between the two domains is not significantly large. According to the authors, this is due to the role assigned to the encyclopedic features within the classifications, as some authors classify them as functional and others place them in their own category. Likewise, there are authors that regard functional features within thematic relations (co-occurrence relationships of objects in specific contexts), and include in this category relations such as “chalk-blackboard” (Kalèneine et al., 2009). Consequently, more relationships of this type are observed for non-living things. Yet other researchers consider that a functional relation is that which links the concept directly with its function (e.g. “shovel-used for digging”) (Johnson, Hermann, & Bonilla, 1995).

It is clear that without a sufficiently explicit and justified feature type taxonomy, any inference drawn on differences between semantic domains and categories is tenuous. For this reason, Wu and Barsalou (2009) have proposed a taxonomy based on empirical data derived from the production of participants in a semantic features generation task. This taxonomy was developed based on the Situated Conceptualization model (Barsalou, 2005) and

proposes a classification system that includes the following levels: Taxonomic; Situational Property; Entity Property; Introspective Property; and Miscellaneous. Each of these levels encompasses numerous subtypes. The factors the authors took into account were as follows: (a) cover the extensive production generated by subjects through feature production tasks; (b) capture the variety of information on ontological kinds (animals and artifacts, among others); (c) consider the correspondence with modality-specific brain regions; (d) reflect established sensory information channels; and (e) reflect introspective as well as sensory-motor experiences (Cree & McRae, 2003). Each proposed feature type was clearly defined and exemplified, thus greatly facilitating the replication of the classification. This taxonomy, which most certainly possesses a greater degree of detail and complexity, is the one we will use in the present study.

Limitations of the Dichotomic Taxonomy

The dichotomy of feature types has been shown to be inadequate to explain the complexity of the conceptual representations of the different semantic categories (Cree & McRae, 2003; Marques, 2005; McRae & Cree, 2002; Moss et al., 2007; Peraita, 2006). In particular, McRae and Cree (2002) have demonstrated that semantic domains are distinguishable not only by sensory versus functional features, but also by many other feature types, and that a more complex taxonomy, such as that proposed by Wu and Barsalou (2009), can better reflect the differences between domains because they more faithfully account for the multidimensionality of the conceptual representation.

For their part, the Spanish-language team led by Herminia Peraita has proposed a semantic memory model with a semantic feature classification that is much richer than the sensory-functional model. This model emphasizes the multidimensionality of the categorical representation, which means that the information that a subject has about the concepts is rich and complex. It not only includes information about multiple modalities, but also diverse types of abstract

knowledge. The conceptual components proposed by these authors are: taxonomic; types; evaluative/perceptual; functional; part-whole; procedural; place/habitat; behavioral activity; lifecycle; and produces/generates (Peraita, Elosua, & Linares, 1992).

Inadequacy of Mere Frequency of Feature Types in Discriminating between Domains

More recent conceptual knowledge organization models also stress the feature composition of semantic representations. For example, the Conceptual Structure Account considers that concepts can be defined in terms of the features that comprise their meaning. However, when it comes to explaining the differential representation of semantic categories and domains, these authors not only emphasize the type of feature, but also consider that these features have various qualities that determine how the concept is activated during language comprehension and production, and how it is affected by brain damage (Moss, Tyler, & Taylor, 2007). In so doing, they affirm that the structure of semantic representations varies in the different domains and categories based on the quantity, quality and interactions among the semantic features that compose them.

A series of lines of recent research have studied the qualities that make a feature central to the definition of a concept (Sartori and Lombardi, 2004; Sartori, Polezzi, Mameli, & Lombardi, 2005; Montefinese, Ambrosini, Fairfield, & Mammarella, 2014); in other words, the variables that determine the feature's contribution to a concept's core meaning. Thus, the following variables have been suggested to characterize features: Distinctiveness; Dominance; Relevance; and Significance.

Distinctiveness refers to the degree to which a feature is or is not shared by various concepts (Devlin, Gonnerman, Andersen, & Seidenberg, 1998; Garrard et al., 2001); in other words, it is a measure of the extent to which a characteristic is unique to a certain concept. For example, "mouth" is a feature shared by many animals, but "trunk" is a feature of an elephant that is barely shared with other concepts. According to

Cree, McNorgan and McRae (2006), distinctive features have a privileged status in the organization of semantic memory because they allow for the differentiation of like concepts.

Dominance is a measure of the frequency with which a semantic trait is produced to define a concept (Ashcraft, 1978). Results have not been reported that indicate that this measure by itself contributes greatly to explain the differences in the semantic processing of domains.

For their part, Sartori and Lombardi (2004) have proposed the Relevance variable, which combines Distinctiveness and Dominance. It is defined as the measure of a feature's contribution to a concept's core meaning (Sartori, Lombardi, & Mattiuzzi, 2005). For example, "long neck" is a feature that is very relevant to giraffe because the majority of subjects use this feature to define this animal, and very few use it to define another concept. The researchers state that a few features are adequate for the precise recovery of a concept when relevance is high, and that recovery is inexact when relevance is low (Sartori & Lombardi, 2004; Sartori, et al., 2005).

More recently, Montefinese, Ambrosini, Fairfield and Mammarella (2014) proposed a variable called Accessibility, which is a measure that includes frequency (or Dominance) as well as the feature's production ranking in the Semantic Features Production Norms. This measure, combined with Distinctiveness, gives rise to Significance. The authors demonstrated its predictive value via feature verification tasks. In this same vein, Vivas, Lizarralde, Huapaya, Vivas and Comesaña (2014) recently developed a computerized algorithm called Definition Finder that processes semantic features using a calculation that is similar to that of Accessibility and combines these two values (frequency and production ranking) in a single value ranging from 0 to 1 and that is assigned to each feature. This calculation is discussed in greater detail in the methodology section and will be used in the present study to analyze the weight of feature types.

Using the variables of the features mentioned up to this point, the studies by Marques, Cappa and Sartori (2011) and Sartori, Polezzi, Mameli and Lombardi (2005) demonstrate that

feature type (sensory vs. non-sensory) plays a secondary role to semantic Relevance in naming from definition tasks. Marques (2005) found similar results when analyzing feature Distinctiveness; this study found that, independently of feature type, distinctive features were more often selected than shared features in naming from definition tasks.

For their part, Zannino, Perri, Pasqualetti, Caltaginore and Carlesimo (2006) compared the Dominance of features across domains and by feature type. This was established under the Semantic Feature Production Norms. The authors found that the advantage of sensory features in the living things domain and functional features in the non-living things domain is observed only when the Dominance of the features is taken into account; similar results were observed when the Distinctiveness of the features is taken into account.

The Use of Taxonomies based on the Semantic Feature Production Norms

The collection of Semantic Feature Production Norms has been a frequently used method to empirically observe data on feature types that constitute the representation of concepts, as well as to establish the contribution of features to the core meaning of concepts. The collection of Norms consists in asking a group of speakers of a certain language to list the features that best define a set of concepts. From these lists, researchers obtain information to identify the semantic feature types that characterize each domain, and to undertake analyses that make it possible to calculate key variables for the features, such as Distinctiveness, Dominance, Relevance and Significance.

Drawing from the published Norms for the English language, Cree and McRae (2003) have studied the typology of features that characterize each semantic domain based on the aforementioned taxonomy proposed by Wu and Barsalou (2009). From the data obtained through the Norms, Cree and McRae calculated the ratio between the number of features of each type and for each domain. The calculation was

based on the quantity of features of each type that appeared as a definer for each domain in the Norms. However, these calculations did not consider two variables: frequency of production (in other words, Dominance) and the feature's production rank. First, the frequency with which each attribute is listed varies and provides valuable information on the feature's importance to the definition of the concept. A feature listed by 5 subjects does not carry the same weight as one listed by 30 subjects. Second, when features are listed in a serial manner, it is also important to consider each feature's rank. If a feature was not only listed frequently but also early on, it is to be expected that its contribution to a concept's core meaning would be greater. In this regard, the Accessibility variable allows for the combination of Dominance and production rank.

This study seeks to contribute to the description of the differences in the composition of semantic features in the living things and non-living things domains using information obtained from the Spanish Semantic Feature Production Norms (Vivas et al., 2016) as well as a complex and well-founded taxonomy, and considering the Accessibility of feature types.

Methodology

Participants

The sample was comprised of 180 Spanish-speaking Argentine university students (122 women and 58 men) with ages ranging from 20 to 35 years ($M = 23.62$ years; $SD = 5.75$), who volunteered to participate under informed consent. The principles of the Declaration of Helsinki (2013) were followed.

Design

Of the Norms' 400 original concepts, we selected a sample of 90 with pictorial referents that were similarly included in the set of images used by Cykowicz, Friedman, Rothstein and Snoodgrass (1997); 60 of the chosen concepts belonged to the living things category (30 corresponding to animals, and 30 to vegetables), with the remaining 30 being non-living things (among them musical instruments, means of

transportation and items of clothing). These concepts were equated for both semantic domains with two main variables in mind: age of acquisition and familiarity, as described in the Argentine norms (Manoiloff, Artstein, Canavoso, Fernández, & Segui, 2010).

Procedures

The data were collected from the Spanish Semantic Features Production Norms (Vivas, Vivas, Comesaña, García Coni, & Vorano, 2016). To construct the dataset, participants were instructed to produce the features that best characterize and describe particular concepts. Following a meticulous process to unify the descriptors produced by participants (for the details of this process, see Vivas et al., 2016), these were then loaded to the Definition Finder program (Vivas et al., 2014). This program generates a list of features for each concept weighted by frequency and ranking. From this process, we obtained a specific value ranging from 0 to 1 for each feature listed for a given concept (relative weights were standardized with scores between 0 and 1 in order to allow for comparisons across concepts). For example, if for the concept “dog” many participants listed “animal” in first place,

this feature would score close to 1, while if few participants listed “guardian” and listed in fourth or fifth place, this feature would score close to 0. Further, these features were codified using the codification scheme proposed by Wu and Barsalou (2009). This scheme was chosen because it is the most complete of those published to date.

Results

The mean number of features listed by participant and by concept in the Norms was 5.07. First, we present the descriptive data for the feature types that were both produced by participants in the Norms, as shown in Figures 1 and 2. Here we can observe the weighted feature types generated for each domain according to its value as calculated by the Definition Finder. The features are presented in descending order by their average weighing for the concepts in the corresponding domain.

We can see that the living things domain is defined mainly by features in the supraordinate category (C-super), followed by external surface properties (E-exsurf), external components (E-excomp) and entity behaviors (E-beh). The other feature types appear with scores below 0.1,

Figure 1. Descriptive of weighted features for Living Things domain.

Figure 2. Descriptive of weighted features for Non-Living Things domain.

meaning that they represent less tan 10% of the total weight of features defined for that concept.

Turning to non-living things, we can see a greater weighing of features in the supraordinate category (C-super), followed by function (S-fun), then external components (E-excomp) and external surface properties (E-exsurf). Figure 3 illustrates the sequence of production for the features with the greatest weights for each domain.

Second, we performed a difference of means T-test to compare the weighted values of each feature type across the two domains. In performing this calculation, for those concepts where there was more than one feature of a certain type (for example, three E-excomp: HAS_FEET, HAS_EARS and HAS_A_TRUNK), we added

the weights obtained for each feature to calculate the value for that feature type (E-excomp in our example) for that concept. For the living things domain, the results indicate a greater weight for the following features: C-super ($T = 3.035$; $p = .003$), S-loc ($T = 3.343$; $p = .001$), S-action ($T = 3.490$; $p = .001$), E-incomp ($T = 1.988$; $p = .05$); E-exsurf ($T = 5.326$; $p = .001$), E-insurf ($T = 3.805$; $p = .001$), E-whole ($T = 2.244$; $p = .027$), E-beh ($T = 4.586$; $p = .001$) and I-eval ($T = 2.998$; $p = .004$). For the non-living things domain, the results indicate a greater weight for the following features: C-subord ($T = -2.135$; $p = .041$), S-func ($T = -7.059$; $p = .001$), E-spat ($T = -2.520$; $p = .017$) and E-mat ($T = -3.819$; $p = .001$). Figure 4 shows the features with a statistically significant difference across domains.

Figure 3. Production order of main types of feature by domain.

Figure 4. Domain differences in feature type's weight.

Discussion

As stated at the beginning of this article, this study aims to describe the feature types that define the semantic domains, seeking to overcome some of the criticisms made regarding sensory-functional models. The first of the criticisms takes issue with the definition of feature types. The “sensory” and “functional” categories are not explicitly defined and differ across different studies. To overcome this hurdle, the present study uses a taxonomy with clear and precise definitions of the classifications used. As specified at the beginning of this article, the taxonomy of feature types we used was empirically drawn from the defining features produced by a group of persons. One can assume that this type of classification more faithfully reflects the qualities of features than a classification established *a priori* by the researcher. Further, each category is clearly described and exemplified, facilitating its use by any researcher who wishes to apply it.

The second criticism pertains to the dichotomic classification of feature types. Numerous studies demonstrate that such a classification is not only inadequate when it comes to differenti-

tating between domains (Cree & McRae, 2003; McRae & Cree, 2002; Moss et al., 2007; Peraita, 2006), but also that, in some cases, it also fails to verify the preponderance of visual features in the living things domain and functional features in the non-living things domain (Garrard et al., 2001; Vanoverberghe & Storms, 2003). The taxonomy used here has five major categories and 44 feature types that have been well-founded both empirically and theoretically. This allows for greater richness in the description of feature types. Its feature types were derived from semantic feature production tasks and its categories were developed based on a Situated Conceptualization model (Barsalou, 2005). Thus, this taxonomy not only allows us to more finely describe the composition of feature types by domain but also to infer the cognitive processing underlying the production of different feature types.

The third criticism refers to the way in which the weight of the feature in each concept is measured. One possibility is to simply compare the number of features of each type that defines each semantic domain. In the most recent studies, the values used to calculate differences by domain

were extracted from the Semantic Feature Production Norms. These norms provide additional information, making it possible to calculate not only the frequency with which a feature is produced for a particular concept, but also the importance of this feature to the definition of the concept in question. In this way, it is possible to analyze the contribution of the different feature types, also considering their relative weight to a concept. As previously stated, there are various ways to measure a feature's contribution to a concept's core meaning (Distinctiveness, Dominance, Relevance, Accessibility, Significance). In the present study, we calculated Accessibility and analyzed the differences across domains in terms of this value. Montefinese et al. (2014) discuss the explicative power of this variable in feature verification tasks and its importance in capturing feature salience in the computation of the significance of concepts. The present study also contributes to demonstrating its validity in weighing the defining features of concepts.

Having overcome these three criticisms, we now turn to the analysis of the results. First, it is worth noting some observed particularities in the description of feature types that characterize semantic domains. The results we obtained indicate that there is a preponderance of features belonging to the supraordinate category for both domains. This means that the feature type that is most frequent and tends to be ranked first is the semantic category that the concept belongs to. In this respect, it is important to underscore that the population from which the sample was selected is comprised of university students. Numerous studies indicate that young adults with high educational levels have a tendency to establish taxonomic classifications above other types of relations (Murphy, 2001; Whitmore, Shore, & Smith, 2004). Therefore, it is to be expected that this study's participants would consider semantic categories as their top concept-classification criterion.

A second notable observation is the predominance of features in the living things domain that refer to sensory properties, especially visual properties, according to the Wu and Barsalou (2009) classification of external surface

and external component properties, as well as the predominance of functional features in the non-living things domain, just like sensory-functional models suggest. Based on this data, we can hypothesize about the underlying cognitive processes, based on the Situated Conceptualization model, and assume that for both domains, a more abstract level is accessed first, implying the delineation of the semantic category, and then, for the living things domain, the simulator corresponding to the individual concept is activated, followed by its context, while for the non-living things domain, situated conceptualization is recurred to first, and then the object's specific simulator.

In third place, we have Entity Behavior for living things and sensory properties (external surfaces and external components) for non-living things. It is worth noting that living things (especially animals) do not, strictly speaking, have a function, and their representation is not static but rather includes a dynamic factor tied to behavior. In this respect, functional and entity behavior features are alike in that they both refer to a thing in action. According to the situated conceptualization model proposed by Barsalou (2005), when we reactivate features associated with a concept, we are partially simulating the encounters we have had with that thing. This conceptualization not only includes a static image of what the thing looks like, but also the actions associated with it, the associated emotions and thoughts, and the elements that form part of the context. In turn, other studies have considered all the features that describe a thing's (animated or not) activity or action as functional features (Garrard et al., 2001).

These results provide information relevant to the cognitive processes underlying the semantic feature production task. When defining a concept, the first thing that occurs is the delineation of the semantic category it belongs to, followed by the appearance of the most significant features for each domain: visual-sensory for the living things domain and functional for the non-living things domain. This is in line with expectations for sensory-functional models. Lastly, the inverse pattern would appear: dynamic fea-

tures for living things (entity behavior) and visual features for non-living things.

Up to this point we have discussed the results that pertain to the description of the feature production flow for each domain. However, another of the present study's objectives was to compare feature types across domains. The data obtained partially coincides with that of McRae and Cree (2002), who undertook a similar study and observed the preponderance of supraordinate, internal surface and entity behavior features for living things, and subordinate, functional and material (or made-of) features for non-living things. Along the same lines, other studies indicate that taxonomic relations (supraordinate category) are more salient for natural kinds and thematic relations (implying knowledge of contextual elements) for artificial things (Kalèneine et al., 2009). Our results allow us to understand this phenomenon inasmuch as living things are mostly defined by the category they belong to and their physical qualities (features found with Entity Properties) and non-living things by their function (feature included by Wu and Barsalou within Situational Properties inasmuch as the thing must be used by someone, which would be an instrument-agent thematic relation).

Despite these similarities, in the present study we also observed a predominance of location, action, internal component, external surface, part-whole and evaluative features for living things and spatial features for non-living things. It should be noted that among the features with significant differences between domains, various of them did not have substantial weight in the composition of the domains' conceptual representations. Therefore, only supraordinate, external surface, functional and entity behavior features fulfill both conditions. This indicates that although the concepts' composition of semantic features is highly rich, there are certain features that have important weight and they define and differentiate the different domains. As previously mentioned, Accessibility is one of the variables that makes it possible to measure this weight.

For future research, it would be desirable to combine Accessibility values with Distinctive-

ness values in order to obtain the Significance of the features used and demonstrate the predictive efficiency of this variable in tasks that require processing that is inverse to feature production, such as feature verification or the recognition of concepts based on the presentation of defining features. These types of tasks would allow researchers to measure whether response efficiency increased due to the Significance of the features, and would contribute to our knowledge of the variables that influence the composition of features of conceptual representations.

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