Classifiers in non-European languages and semantic impairments in western neurological patients have a common cognitive structure

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Abstract

We compared two non-overlapping data sets: (a) the semantic categories in representative samples of nominal classification languages (N = 334); and in a non-overlapping population (b) semantic category-specific impairments of European neurological patients (N = 121). Each of these appears to organize world objects in natural kinds (e.g., animal, body part, plant, fruit and vegetable, liquid) or manmade kinds (e.g., food, clothing, tool, vehicle, furniture). We show that whenever a specific semantic category is found as a cognitive impairment, this category also exists in some language as a semantic classifier. Since all of the existing semantic impairments reports are with speakers whose languages lack semantic nominal classification systems, the present regularities between grammar and cognitive deficit suggests the idea that cognitive universals may constrain how the neural substrate of knowledge is organized and can break apart but also how they can become expressed in different grammars.

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Keywords: Category-specific semantic impairments; Classifier languages; Semantic deficits; Brain's semantic system; Semantic universals

1. Introduction

In this review and survey of two literatures, we present a striking commonality between linguistics and neuropsychology on the mind’s semantic system: There appear to be remarkable regularities in two seemingly unrelated phenomena, each described within two very different fields of study: linguistics and neuropsychology. On one hand, linguists know well the existence of nominal classification systems in many languages across the world (Aikhenvald, 2000, 2017; Aikhenvald and Mihas, 2019). On the other hand, neuropsychologists have documented several cases of patients showing knowledge impairments in rather specific semantic categories after brain damage (Warrington and Shallice, 1984). Importantly, the patients studied so far spoke languages where nominal classification systems principally based on semantics are absent and therefore they constitute an entirely non-overlapping population of

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individuals (in Western societies in Europe and North America) from peoples speaking classifier languages. On these grounds, one can surmise that the structures of the languages that these patients spoke did not play any causal role for the types of cognitive deficiencies that they suffered. That is, the loss of these specific semantic categories cannot be reduced to a match of conventionalized or previously learnt, linguistic categories. Instead, we would like to argue that this correspondence constitutes a convincing case for the presence of an underlying commonality in cognition and reveals an alignment across these two completely separate fields of enquiry. As examples, consider how in Vietnamese one would need to use the classifier cây when counting (with numerals) or pointing out (with demonstratives) any kinds of fruits, plants, trees or vegetables. The translations of cây in the squared brackets are redundant in non-classifier languages (e.g., English) but in Vietnamese supply mandatory superordinate category information (the phrases were controlled for correctness by native speaker and linguist Jenny Tran, cf. Tran, 2011):

(1)  

\begin{align*} 
\text{một cây} & \quad \text{xu'o'ng rồng} \quad \'\text{A [plant] cactus'} \\
\text{một cây} & \quad \text{ngò} \quad \'\text{A [plant] coriander'} \\
\text{một cây} & \quad \text{mía} \quad \'\text{A [plant] sugarcane'} \\
\text{một cây} & \quad \text{chuối} \quad \'\text{A banana tree'} \\
\text{một cây} & \quad \text{cá chua} \quad \'\text{A tomato plant'} \\
\text{một cây} & \quad \text{sen} \quad \'\text{A [flower] lotus'} \\
\text{một cây} & \quad \text{súp-lọ} \quad \'\text{A [vegetable] broccoli'} \\
\text{một cây} & \quad \text{hành} \quad \'\text{A [vegetable] onion'} \\
\text{một cây} & \quad \text{đưa hâu} \quad \'\text{A [vegetable] pumpkin'} \\
\text{một cây} & \quad \text{dí} \quad \'\text{A [fruit] guava'} \\
\text{một cây} & \quad \text{khé} \quad \'\text{A [fruit] carambola (starfruit')}
\end{align*}

Then consider a case of impaired knowledge for fruit and vegetables, as studied by Samson and Pillon (2003). This French-speaking patient suffered a stroke on the left side of the brain, which resulted in some naming problems. Importantly, in all semantic tasks (picture naming, naming to description, matching a word to a picture, providing a description from a word or a picture, verifying attributes), the patient had a disproportionate problem with fruits and vegetable items, compared to other classes (e.g., animals, artifacts). Crucially, the problem was greater when no name production was required (e.g., when verifying whether an attribute applied or not to the item: its taste, cuisine, natural environment), thus pointing to a ‘semantic processing level’ deficit and not a word production or comprehension problem.

The simple fact that French does not include in its grammatical repertoire a ‘fruit and vegetable class’ rules out the possibility that the language spoken by the patient plays a direct causal role for their deficits. Again, we need to stress that, according to the neuropsychological literature; all the patients reported (a bit over a hundred) so far have been speakers of languages where the corresponding semantic categories reported for these patients were absent (see Supplementary material, supplement 1 for information about the patients’ native languages; Corbett, 1991; Aikhenvald, 2004). Thus, there is the possibility that some other underlying factor has to be common for the two phenomena to emerge in such different but related ways. We suggest that this commonality may be widespread and hard to believe to be chance coincidences. That is, human cognitive structure may be common across languages and cultures in evolutionary history and developmental processes, in shared experiences with an unchanging physical world, which jointly shape the human mind to be prepared for specific but recurrent domains of knowledge.

Indeed, in recent decades, two parallel debates have taken place within cognitive neuroscience (neuropsychology) and linguistics, with negligible interactive discussions between these fields. The “category impairment debate” within neuropsychology has led some scholars to conclusions based on neural or linguistic evidence (Caramazza and Mahon, 2006; Mahon and Caramazza, 2009) that should be in principle valid for all humans. A similar discussion has emerged within linguistics in relation to the so-called classifier languages (Aikhenvald, 2000), claiming that the typology of noun systems gives us clues to how humans in general conceptually organize their world, regardless of whether a specific noun system emerges in a South East-Asian language but it is absent in the Indo-European languages spoken in Europe or the United States. Hence, by documenting – with the present survey – a systematic co-variation of semantic deficits with the independent body of data on nominal classifier systems, we hope to provide converging evidence for models of semantic systems and present a clear case of how the study of language can provide a window into human cognition in general (cf. Pinker, 2007). Regularities in both patterns of impairment (Cree and McRae, 2003) and cross-cultural language devices could be used to derive constraints on possible theories of semantic memory or the neural organization of world knowledge.

Linguists have been familiar with the phenomenon of nominal classification systems for at least about a century (e.g., Royen, 1929). Lakoff rekindled the interest, with his 1987 book “Women, Fire, and Dangerous Things”, by putting forward the idea that classifiers can actually reveal something crucial about the human mind. One clear function of classifiers is to
narrow down the scope of reference when people talk about objects in the world, as shown in the Vietnamese examples above, and to assist keeping track of referents in discourse (much like anaphora in discourse). Intuitively, this would improve efficiency of communication by directing the listener’s attention to a particular pre-established category, in line with Talmy’s linguistic function of a “windowing of attention” (Talmy, 2000).

Within the wide variety of classifier languages, the linguistic expression for nominal classification can be anywhere on a scale from lexical (word-based) to grammatical (reduced forms or affixes). It can be ‘numeral’ in counting systems or ‘concordial’, when grammatical markers are attached to determiners or adjectives within the noun phrase, or to clausal constituents such as the verb (e.g., Swahili). Numeral systems appear to have classes in the hundreds while concordial systems, known as noun classes or genders, have on the average five to twenty classes (Corbett, 1991, 2013). These types are dispersed in particular geographical areas of the world; grossly speaking, numeral systems are largely found in Asia and Mesoamerica, concordial systems in Africa, while possessive systems are found in Oceania (Aikhenvald, 2000).

The scope of the present study are nominal classification systems that organize in semantic categories, including numeral classifiers, noun classes/genders, noun classifiers, possessive classifiers, verbal classifiers and classifieric verbs, and more rarely, deictic classifiers (for a definition of these types, see Aikhenvald and Mihaljević, 2019: 2–6). In numeral classifier systems we avoided classifiers that measure mass quantities or arrange objects in sets (since these do not primarily organize entities by their conceptual makeup) and focused instead on the so-called sortal classifiers. For practical reasons we refer to all these devices collectively as classifiers. Classifiers typically represent classes of nouns by their semantic ‘essence’; like: ‘a HUMAN carpenter’, ‘a PLANT banana’, ‘an ANIMAL dog’, ‘a LIQUID river’; shape properties: ‘a LONG OBJECT tree/pencil/bone’, ‘a FLAT OBJECT leaf/paper/sheet’, ‘a SPHERICAL orange/fist/baby’; function: ‘a TRANSPORTATION boat’, ‘a DRINKABLE fruit juice’; social status or kinship relations between humans: ‘HONOURABLE Mary’, ‘YOUNG MALE Kin Peter’ (Craig, 1992: 280).

A crucial aspect of this linguistic phenomenon is its ubiquity, since grammatical devices for organizing nouns based on what these nouns mean and refer to in the real world are found in highly unrelated languages spread out in disparate and distant geographical regions (cf. Fig. 1). Although studies document a wide variability across languages, they also uncover striking commonalities. That is, inventory sizes and superficial expressions can have very different forms, but their semantic bases appear astonishingly similar. This also suggests that contact among languages alone or the inheritance of structural features along languages with a common origin cannot account for their grammatical organizations, a fact that has intrigued linguists for decades and especially since Allans seminal article in 1977.

Entirely independently of the linguistic structures described above by linguists, around the 1980s emerged the first reports within neuropsychology of individual patients showing strikingly selective losses of knowledge in identifying or expressing knowledge about superordinate categories of objects, such as animals or plants. At present, slightly more than a hundred cases have been documented showing selective loss within their semantic repertoire (Shallice and Cooper, 2011). A variety of causes (e.g., infective diseases to the brain, head injury, stroke, and neurodegenerative illnesses like Alzheimer’s) can lead to these symptoms. Much of the debate, within the cognitive neurosciences, has originated about the underlying causes of these impairments, in particular the implications that these “dissociations” may bear for models of the cognitive and neural organization of human knowledge and their origins (Mahon and Caramazza, 2011).

What is most relevant about these semantic impairments for the present goal is that the categories so far identified appear to correspond to ‘kinds’ or ‘object domains’. For example, the first described case of category-specific semantic impairment was proposed to show dissociation between the knowledge of “living things” vs. “non-living things” (Warrington and Shallice, 1984). According to the evidence, when asked to provide an object’s definition (e.g., what is a whistle? What is a kangaroo?), some neurological patients might provide semantic information (e.g., a whistle is a ‘thing you blow to make a piping sound’) about an inanimate (artifact) object that is preponderantly correct (about 75% on average across patients). However, they may be correct only for about 20% of semantic information about animate (living) things (e.g., the kangaroo may be declared to be ‘an animal that swims’; Shallice and Cooper, 2011). Crucially, other patients might show the converse pattern (Warrington and McCarthy, 1983, 1987): A clear impairment for inanimate objects but a relative superiority for animate objects; a state of things known within cognitive neuroscience as a ‘double dissociation’ between deficits (Shallice, 1988) or a cross-over interactive effect, which might be problematic to explain without positing two partially-independent semantic systems (and neural networks) (however, see Farah and McClelland, 2013 for the opposite view, i.e., that a connectionist architecture with separate systems by modality with weighting by category can give rise to double dissociations). Importantly, if such a deficit is truly about conceptual knowledge, it will be expressed simultaneously in very different tasks, like picture naming, distinguishing among basic-level items within the affected category, or providing definitions or answering questions probing semantic information (e.g., ‘does a whale have legs?’).

In one review of the well-documented cases at the time (Capitani et al., 2003), cases with category-specific deficits affecting a “biological” category (i.e., animals or fruits and vegetables) were the most frequent (N = 61), cases having a specific deficit for “artifacts” (e.g., manmade tools) constituted a smaller set (N = 17). Another review by Gainotti (2000) reported a similar asymmetry. Most intriguingly, other reports within the neuropsychological literature indicate the
presence of deficits restricted to narrower or relatively subordinate categories than those across the broad animate/inanimate distinction (e.g., a deficit specificity with ‘body parts’; Shelton et al., 1998). As seen before, fruits or vegetables (in a few cases including a reliable impairment for the narrower category of ‘food’) can stand out as impairment. In 2009, Mahon and Caramazza confirmed that there were disproportionately more cases impaired for the ‘animals’ category than other categories (e.g., tools, musical instruments). Importantly, the observed specificities were neither the result of unbalanced or not well-controlled stimulus sets in the tests (i.e., causing dissociations as experimental artifacts), nor due to differences in the patient’s knowledge of the category in question. In fact, one patient with a selective problem naming fruit and vegetable was actually, before the illness, a real expert in gastronomy (Humphreys and Forde, 2001).

To summarize, the presence of commonalities across very different languages, indicates that there are shared constraints on the variations (Malt and Majid, 2013). By revealing common aspects across language and neuropsychological data, the results have crucial implications for cognitive science and provide important lessons about the nature of human cognition. Such constraints may be imposed by the neural architecture of our brains (i.e., the cross-modal, sensory, cortical surface maps and their network connectivity; Mahon and Caramazza, 2009, 2011; Chen et al., 2017) together with the cortical representations of actions (praxis). In turn, the architecture may respect evolutionary pressures that privilege domain-specific knowledge domains (e.g., animals, tools, people; Caramazza and Mahon, 2003). Other forces at work, in shaping either diversity or commonalities, may derive from human basic activities or habitats that vary across cultures or shared and salient structures that may be ‘crying out to be named’ (Malt and Majid, 2013) so that knowledge is acquired in much the same way. Most likely, there is interplay between constraints imposed by the structures of our bodies and of the physical environment or objects (e.g., in Chipewyan, dough-like and mud-like objects are classified together; Carter, 1976). Moreover, the current neuropsychological evidence indicates that there exist general domains of semantic knowledge that can be selectively impaired like ‘biological animate’ (e.g., animals), ‘biological inanimate’ (e.g., plants), or ‘non-living inanimate’ or ‘artifacts’ (e.g., tools). However, crucially, this literature also
documents selective impairments within subordinate categories (e.g., musical instruments, food) of some of the general domains above. In fact, commonalities between impairments and classifiers may be strongest at an “intermediate” semantic level, where classes can be more specific (e.g., fruits and vegetables) than the typical high-level superordinate domains (e.g., living, inanimate) mentioned in the neuropsychological literature. Indeed, some commonalities may be as subordinate as the “basic level” (e.g., dogs) of natural discontinuities among objects in the world (Mervis and Rosch, 1981). Noteworthy also, although outside the scope of the present investigation, is the fact that the categories known to category-specific impairments remarkably parallel the categories that result from the functional imaging literature (see for example Mahon and Caramazza, 2011). Moreover, a match of neuroimaging research on semantic parameters that underlie classifier systems is discussed in Kemmerer (2017).

Hence, based on the general assumption of universality of human cognitive structure and the importance of language features as windows into a universal human mind, we made the following prediction: If there exists a semantic category that is affected in cognitive impairment, this category will be likely to exist in some classifier language (e.g., if knowledge of ‘vehicles’ can be disproportionately impaired in at least two well-documented cases, then ‘vehicle’ classifiers are likely to exist in language).

With the following survey and our initial results, we hope to inspire linguists and neuropsychologists to transcend their traditional disciplines, to expand their approaches and methods and to seek alternative explanations than were previously acknowledged within their fields.

2. Methods

We adopted a data-driven approach since by ignoring previous accounts of the brain’s and languages’ semantic systems we can best reveal the shared semantic systems in the two fields of study. Hence, we will present here no overarching theoretically motivated taxonomy or ontology that could have driven the data collection, which to be thorough and the most inclusive as possible, in our opinion, should be blind to any theoretically driven ideas about such systems.

2.1. Registration processes

2.1.1. Registration of the superordinate categories in impairments

The following is an account of how we computed the presence of a more generic semantic impairment, based on the registrations more closely described in Sections 2.2.1 and 2.2.2. Table 1 presents a survey of which patients were assigned to impairments in the Living things, Non-living things, Inanimate, and Man-made objects’ categories, as well as which patients did not clearly show either a Living thing or non-living thing deficit (e.g., patient DM94 was impaired for animals and insects in the animate domain, but also for musical instruments and vehicles in the inanimate domain). Many studies presented statistics for response patterns of stimuli belonging to either the living thing or non-living thing domains, although not for the individual subcategories. Table 1 presents the distribution of these patients. The patient labels can be checked in Supplementary materials (Supplement 1).

Table 1

| Superordinate category | Based on statistics of undifferentiated categories | Based on independently impaired categories |
|------------------------|---------------------------------------------------|--------------------------------------------|
| Living things (49)     | Adam, BAR, CA93, CW97, DM97, EA, FA, FI, JBR, JH, LF, MB, NA, NR, RC, TU. | AMA, AN, BD, Boswell, CCA, DW, EC, ELM, ER, FAV, Felicia, FM, GIZ, IL, JB, Jennifer, JL, KS, KQU, LA, LH, MA, Michelangelo, MS, MU, NV, RG, RM, RC, SB, SGE, SRB, VV, NB, CA97, CG, CH, CN94, CN98, CW92, DRS, GP97, KH93, PL, VP |
| Non-living things/man-made artifacts (17) | ES, IW, M. Lucien, SM, VER | Dante, DB, EW, FS, GC, KR, Giulietta, Helga, KB, KS, RC, ME, MC59, Mr.W, MC72, PR, SBY, SE, TOB, TS, VG |
| Animate (only animals) (20) | | MF, YOT |
| Inanimate (plants + artifacts) (2) | | JV, MD, NR, WK, WMA |
| Inanimate (plants only) (5) | | BAI, DF, DM03, DM94, Emma, FB, FM03, GA, GC03, GP98, HJA, ING, IOC, JH, JH03, JJ, JMC, JP, KE, MB03, MIO, PJ, PS, PSD, PCO, RS, SL, SP |
| No distinct pattern of superordinate category impairment (28) | | |

Patients sorted according to their semantic deficit at the superordinate level. First column presents type of superordinate category, the next columns list patients according to how a deficit for a superordinate category was computed, based on a statistical significance of stimulus types not arranged into subcategories (second column) or based on multiple separately impaired subcategories within the superordinate category (third column).
In impairments, the living things superordinate level includes all recorded patients with animal and plant/flower/fruit and vegetable impairments but no non-living impairments, and patients where living things on the whole were statistically more impaired than non-living things (some studies did not provide scores for subcategories, only for the living thing/non-living thing division). The Non-living things superordinate level includes patients who are significantly more impaired for non-living things (i.e., tools, furniture, clothing, vehicles, weapons), than living things. The Animate superordinate level encompasses those patients who were impaired for living beings (animals, dogs, fish, birds, insects) but not for plant life (plants, flowers, fruits and vegetables). The Inanimate superordinate level refers to patients with a deficit for man-made artifacts together with plant life. It turns out that five patients were impaired only for plants. In twenty-eight cases there was no clear division between these superordinate categories. However, the present co-occurrence analyses include all patients (Figs. 5 and 6).

2.1.2. Registration of the superordinate categories in classifiers

In the Classifiers’ data set, we registered as superordinate animate those used as general classifiers for animate beings, i.e., human and non-human animals (e.g., Yucatec Maya), exceptionally including marginally animate entities like insects (Trukese) or microbes (Navajo). For example, the classifier –wor in Motuna classifies in one and same category ‘person, child, pig, bird, fish, snake, centipede’. Some superordinate animate classifiers may include marginally ‘animate’ nouns like celestial bodies (Chontal), spirits (Kiribati) and human shadows (Warndaman). A few languages have animate classifiers that exclude humans (Brou, Gikuyu, Kantu and Khmu). Superordinate inanimate classifiers refer to ‘things in general’ or all things non-human and non-animal. Four grammars explicitly specified the inclusion of plants, fruits or vegetables in the inanimate classifier, e.g., ‘organic and non-organic naturally occurring entities and artifacts (classifier bij- in Indonesian), ‘inanimates including plants’ (Mixtec; Tonga), and ‘inanimates plus fruit’ (Samoa). One language had a classifier that could correspond to non-living things, since these superordinate classifiers include items that cover all things non-human, non-animal and non-plant (p’ée: Yucatec Maya).

2.2. Data collection

2.2.1. Sampling of classifiers

We conducted a systematic library search about classifier systems, using the keywords “classifier”, “noun classifier”, “class”, “noun class”, “numeral classifier” and “gender” to identify the types of semantic categories present in the classifiers of the individual languages. Registering a classifier in a particular category was based either on an explicit statement by the author or through a citation from other sources (e.g., “tek [numeral] C[classifier] ‘count plants and standing trees...’”; Knowles, 1984: 276, 278), or directly from a concrete example where the classifier or class meaning was given in the glossing. See (2) for an example of a classifier (CLF) following the numeral and preceding the modified noun in Mongghul (Faehndrich, 2007: 135).

\[
\text{(2) } \text{ nga-n} \text{-la } \text{nige } \text{dz} \text{en} \quad \text{ger } \text{pas-Ga-dz-a} \\
\text{3PL.STEM one } \text{CLF:BUILDING house stand.up-CAUS-PERF-OBJ} \\
\text{“They built a house.”}
\]

Every item was registered together with information about language names with unique ID numbers, sources of reference, besides geographical area, language family, number of speakers and the year of census, the latter obtained from the online resource Ethnologue.com published by the Summer Institute of Linguistics (SIL) (see Table 2). Registered classifier morphemes were illustrated with specifications or example nouns wherever possible (see Table 3). We excluded classifiers judged to be too narrow and particular to the culture (e.g., types of animal droppings in the Baniwa hunter society; Aikhenvald, 2000: 290) and noun classes/genders where semantics was diverse and had no apparent core.

We stress that any typological similarities across languages are independent of language family or even a shared geographical environment (cf. Song, 2014). In fact, we are interested in the semantic parameters that independently recur across classifier types. All of these types characterize an individual or object. For example, classificatory verbs and verbal classifiers are not, as the label may lead to believe, about verbal actions, but rather about how the objects of certain verbs

| Table 2 | Example of how classifier languages were registered. |
|---------|-----------------------------------------------|
| Language | Source of reference | Continent | Country | Language family | Number of speakers | Year of census |
| Gumuz   | Ahland (2012)       | Africa    | Ethiopia | Nilo-Saharan, Komuz, Gumuz | 179,000       | 2007          |
are handled, their physical propensity, dimension or inherent posture (Aikhenvald, 2000: 295–299). The classifier systems represented in the language sample in the data set were distributed with frequency of occurrence: numeral classifiers (141), noun classes (95), genders (49), noun classifiers (38), possessive classifiers (35), verbal classifiers (16), locative classifiers (4), classificatory verbs (4), deictic classifiers (2), class terms (1) and personal classifiers (1). Note that the aggregated number of these systems (386) supersedes the number of languages in the data sample since many languages have multiple systems. However, in languages with multiple systems, data may not be recorded from all co-existing systems, since we were interested in the semantic-based classifiers only.

All registered items were assigned to one of 45 semantic categories emerging from the data (including superordinate animate/inanimate categories and 51 if shapes are counted individually) in addition to the 43 subordinate categories in Tables 7a–7c):

- Abstract concepts, Animals, Animate, Avian animals, Aquatic animals, Body parts, Books, Buildings, Clothing, Color, Decorations, Dogs, Emotions, Fabrics, Fire/light, Flowers, Food, Fruits, Furniture, Human, Human female, Human male, Inanimate, Insects, Kinship, Liquids, Letters, Materials, Musical instruments, Nature/locations, Occupations, Plants, Plant parts, Shapes (flat, interior, irregular, long, round/curved, square, tiny round and size), Social rank, Songs, Speech, Time units, Tools (including kitchen utensils), Valuables, Vegetables, Vehicles, Water vessels, Weapons and Wild animals.

Some impairment studies tested fruits and vegetables separately but together in several others. Indeed, languages can also share a class/classifier for fruits and vegetables (e.g., Apalai), although it seems more common with one classifier for fruits and another for vegetables. The initial list of categories was created based on literature reviews (e.g., Aikhenvald, 2000) and verified and expanded during the data collection process. Some more subtle semantic distinctions were initially included that we found evidence for in an early stage, but these turned out to be very rare in the total material and were therefore merged: e.g., a distinction between plant and flesh food found in some Australian languages, and between land vehicles different from aerial vehicles (in Japanese).

Classifiers often represented the superordinate categories for animacy. We cataloged a language as having a classifier for animate if humans and animals shared a classifier. If, however, humans and animals were separated in two classifiers, these were assigned separate entries as ‘human’ and ‘animal’ classifiers rather than the single ‘animate’. In some cases though, a language (e.g., Korean) had a general animate classifier while also having human and animal classifiers and these were all registered. Inanimate classifiers were registered as positive instances if generally used with non-living referents. The sources did not necessarily provide the full inventory; hence we could register only those categories that were described in the linguistic literature. The sampling process was blind to which geographical regions where languages were spoken and to which language families these languages belonged. Despite this, the resulting languages were distributed across five continents, besides Oceania (see Fig. 1). Information about the individual languages’ locations, noun classification type and language family can be found in Supplementary material, supplement 1. In total, we included a final 334 languages and the number of speakers in the present language dataset represents near half of the world population, covering about 3.4 billion people and comprising 50 language families (see Table 4). The present classification of the world’s languages is more conservative than that of Ruhlen (1991), which lists only 27 language families (Rijkhoff and Bakker, 1998). Ethnologue (www.ethnologue.com) acknowledges 151 language families, excluding unclassified languages, pidgins and creoles. Hence, the present survey is a highly representative and inclusive sample of linguistic data.

To the extent that the data are uneven, it could be due to language typology: certain geographical areas are known to be ‘classifier hotbeds’; e.g., Mesoamerica and Southeast Asia. Geographical clustering may derive from language contact or a common genealogy. For areal concentrations to occur in grammatical classes, many centuries of prolonged contact are usually required to affect closed classes of a language (Hickey, 2012). Likewise, languages that are related by a common ancestral origin can inherit features from their shared protolanguage and cause clusters, since cultural evolution privileges the preservation of linguistic structure through time. In our material, the representation of classifiers distributed across as much as fifty language families, however in some of the families language representation was restrained by
The paucity of classifier languages due to language death (e.g., Amerindian languages). Hence, these groups may be too small to allow any generalizations to be made about semantic category frequencies. This may not be fatal to the survey, since there are many ways to go about language sampling, and here we selected a method more reminiscent of the macro-area approach (Miestamo et al., 2016). Within the alternative sampling for variety accounts, there is a danger of circularity if one first defines an area on the basis of typological similarity and then uses it as a basis of stratification in

Table 4
Language families in the database with number of speakers from the included languages, and continent where the languages are spoken. The information was drawn from Ethnologue.com, November 2019.

| Language family       | Number of speakers in data set | Continent          |
|-----------------------|--------------------------------|--------------------|
| Afro-Asiatic          | 53,393,410                     | Africa             |
| Algonkian             | 33,430                         | North America      |
| Australian            | 5361                           | Australia          |
| Austro-Asiatic        | 104,283,386                    | Asia               |
| Austronesian          | 274,267,271                    | Oceania            |
| Barbaconan            | 14,100                         | South America      |
| Border                | 4250                           | Oceania            |
| Caddoan               | 25                             | North America      |
| Cariban               | 21,160                         | South America      |
| Chibchan              | 11,100                         | Mesoamerica        |
| Chinookan             | 0                              | North America      |
| Cochimi-Yuman         | 690                            | North America      |
| Creole, Kongo-based   | 1,490,000                      | Africa             |
| Dravidian             | 149,873,650                    | Asia               |
| Eskimo-Aleut         | 75,000                         | North America      |
| Eyak-Atabaskan        | 179,234                        | North America      |
| Guaikuruan            | 35,950                         | South America      |
| Haida                 | 13                             | North America      |
| Hmong-Mien            | 312,450                        | Asia               |
| Indo-European         | 445,454,200                    | Asia               |
| Indo-European         | 534,335,730                    | Europe and South America |
| Iroquoian             | 3086                           | North America      |
| Isolate languages     | 4662                           | Australia, North America, South America |
| Japonic               | 128,350,830                    | Asia               |
| Khoisan               | 7300                           | Africa             |
| Koreanic              | 77,264,890                     | Asia               |
| Ko'a                  | 20,200                         | Africa             |
| Maipurean             | 34,670                         | South America      |
| Mayan                 | 3,201,680                      | North America      |
| Mixe-Zoquean          | 26,000                         | North America      |
| Mongolic              | 152,000                        | Asia               |
| Nakh-Daghestanian     | 1,825,250                      | Asia               |
| Nambikwaran           | 1200                           | South America      |
| Niger-Congo           | 272,820,880                    | Africa             |
| Nilo-Saharan          | 1,665,280                      | Africa             |
| Oto-Manguean          | 96,600                         | North America      |
| Papuan South-Central  | 700                            | Oceania            |
| Sahaptian             | 100                            | North America      |
| Salish               | 427                            | North America      |
| Sepik                 | 11,210                         | Oceania            |
| Sino-Tibetan          | 1,326,019,810                  | Asia               |
| South Bougainville (Papuan) | 26,600                  | Oceania            |
| Tai-Kadai             | 70,917,220                     | Asia               |
| Tarascan              | 55,000                         | North America      |
| Torricelli            | 29,900                         | Oceania            |
| Totonacan             | 18,100                         | North America      |
| Trans-New Guinea      | 303,900                        | Oceania            |
| Tucanoan              | 7700                           | South America      |
| Uto-Aztecan           | 27,516                         | North America      |
| Wakashan              | 130                            | North America      |
| Yaguan                | 5300                           | South America      |
| Yanomaman             | 16,200                         | South America      |
typological sampling (*ibidem*: page 240). Therefore, in order to establish which semantic categories could potentially be part of a universal semantic system, we sorted the semantic data by geographical region; the results are shown in Fig. 1. Based on the language data alone one could assume that those classifier categories that have the *greatest distribution across macro-areas* are more likely to be semantic universals.

In addition, we looked at the distribution of classifier categories across an unrelated typological feature: word order. In Fig. 2, we see that semantic categories in classifier systems distribute across word order types SVO, SOV, VSO, VOS, OSV and OVS, as well as in languages with no dominant word order and languages that accept more than one word order type. The data on word order were drawn from reliable online sources, the World Atlas of Language Structures (WALS; Dryer and Haspelmath, 2013), and Ethnologue.com (www.ethnologue.com, 23rd edition). In these databases, 117 languages in our data set did not provide information on basic word order, and were excluded from the survey displayed in Fig. 2. An overview of languages and word order types, including the 117 missing languages (NG = not given) is provided in Supplementary material.

Across the two distributions in Figs. 1 and 2, some categories recur in wider and some in narrower distribution, as shown in Table 5.

Note that we included here only noun classification devices that classified nouns based on their semantics and excluded systems where assignment to classes is wholly or partly based on phonology, thus excluding many gender systems. Importantly, we registered what appeared to be the semantic cores of classifiers (i.e., the central meaning of a specific classifier). For example, inanimate classifiers were registered as positive cases if generally used with non-living referents; however, some linguistic societies allow borderline usages of an inanimate classifier such as insects (e.g., Indonesian), but we deemed this not to interfere with the semantic core since they did not define overall class semantics. (Semantically it makes sense that insects are attributed to a class of inanimates for being ‘inanimate-like’ or insignificant to humans rather than the other way around (e.g., no language had inanimates + mammals in the same class). Arguably,
what constitutes a semantic core can be different from the speakers’ eye and a ‘Western eye’, for example, in Santali trees are considered ‘animate’ (Neukom, 2001: 108) and for reason of difficulty in cross-linguistic comparison, Santali was then not included in the data set. Conversely, a language may have more than one classifier for a semantic domain, e.g., one for larger and one for smaller animals (e.g., Japanese), in such cases we counted only one since size is orthogonal to several domains. In fact, the range of animal types covered by an animal classifier varies from language to language. Some include only mammals, others fish and insects as well, and some only domestic or pets. Registration of varying levels of semantic granularity can still be defended since a language may show a ‘generic’ Animals classifier as well as a more specific one for dogs (e.g., Cahuilla has a dog classifier metx- as well as one for greater animals; in contrast in Sesotho, the noun class n-ldin- is used for animals including dogs and tigers). Hence, in our analyses (e.g., Fig. 4), Cahuilla contributes to the classifiers’ counts with one generic Animals classifier as well as with a more specific one for dogs. Many languages use classifiers to specify an object’s shape along very specific dimensions. Since our method required that we be blind to the hypothesis of the study we initially analyzed all shape classifiers along the commonly observed dimensions long/flat/round/curved/square/irregular shaped; thin/thick; hollow/compact; rigid/flexible; sharp-pointed/blunt; vertical/horizontal; two-dimensional/three-dimensional extension, and less commonly, flat shapes hinged at one side (e.g., foot, door) and small/big size, sometimes along with consistency (solid/soft) (see Supplementary materials, supplement 1); however we later collapsed all shape classifiers into one category of “shape” in the co-occurrence analyses (Figs. 5 and 6) and present only the more acknowledged shape types in Fig. 3. Indeed, these finer distinctions seemed not to have a counterpart in semantic impairments (cf. Arguin et al., 1996).

2.2.2. Sampling of category-specific semantic impairments

We searched for articles in science databases, using different combinations of key words like “category-specific”, “impairments”, “categories”, “biological” “living and non-living”, “animate and inanimate”, and “lesion”. In total, we scrutinized 121 cases reported in 116 individual research articles. Some reported selective impairment for living things, mammal artifacts, and impairment for ‘fruit and vegetables’, for animals, or for ‘fruits, vegetables and animals’. We gathered data irrespective of the motivations or the underlying theoretical accounts of the researchers. We did not base the data collection exclusively on results from previous reviews, since some of these did not report all the tested categories, in some cases only a subset that was relevant to their hypotheses (e.g., Gainotti, 2010, reviewing only the fruit/vegetable category). Since results from control groups were presented either as percentages, raw scores, compared to the mean scores or ‘range’ of controls, we adopted a practice of registering positive instances of impairments when a patient’s test score was lower than the worst control or lower than the control mean (when range was not available). Thus, our criterion for accepting that the reported case had a specific impairment was either that the patient was significantly more impaired for one or more semantic categories however after nuisance variables like frequency and familiarity had been accounted for, or that the patient performed lower than the lowest performing control subject. Only exceptionally did the studies report whether a patient performed significantly worse than the worst control. This seemed the most accurate approach since the available research reports used rather different measures to conclude for a deficit: (a) the patient was his/her own control (e.g., patient MS, Young et al., 1989). A common expression is the phrase ‘the patient is disproportionately impaired for one category over another…’. Statistical comparisons could occur across semantic categories (e.g., animals relatively to tools, etc.) but in the same patient. The overall most common statistical measure was the Chi-squared test to determine differences between expected and observed frequencies of errors in one or more categories. Most reports, (b) compared the patient’s performance to control groups, matched to the patient in age,
Table 6
An example of registered impaired categories in two patients (the table shows only a subset of the registered categories).

| Research articles            | Patient | Animals | Dogs | Aquatic animals | Avian animals | Fruit/vegetables | Food | Tool | Furniture |
|------------------------------|---------|---------|------|-----------------|---------------|------------------|------|------|-----------|
| Forde et al. (1997), Humphreys et al. (1997) | SRB     | 1       | 1    | 1               | 0             | 0                | 0    | 0    | 0         |
| Hart et al. (1985)           | MD      | 0       | 1    | 0               | 0             | 0                | 0    | 0    | 0         |

educational background, and sometimes gender. A few studies also used “patient controls”, in which case the controls had sustained some other brain damage or disease.

It was however crucial that the authors concluded for a semantic category deficit when this could not be ascribed to other factors (e.g., a perceptual problem or agnosia, or a general naming deficit) and based on the cumulative results from a variety of category identification tasks. Typically, using tests like picture and real object naming, naming to definition, word-picture matching, verbal fluency tasks, object categorization, object decision of real vs. chimerical animals/objects, word definition, copy drawing and drawing from memory, and conceptual knowledge tasks.

Table 6 shows how impairments were registered. The tested categories are represented by a 1 (for an impaired category) or a 0 (for spared categories). Untested categories appear as blank squares.

All registered cases were assigned to one of the following 30 categories:

Abstract concepts, Animals, Aquatic animals, Avian animals, Body parts, Buildings, Clothing, Color, Dogs, Fabrics, Emotions, Food, Flowers, Fruits and vegetables, Furniture, Insects, Letters, Liquids, Materials, Musical instruments, Occupations, Plants, Small manipulable objects, Songs, Time units, Tools (including kitchen utensils), Vehicles, Water vessels, Weapons and Wild animals.

Upon closer scrutiny of the test results we found that there was little basis for the case of a specific impairment in some of the categories, and impairments that occurred in only one patient were excluded from the estimate and we cautiously considered an impairment as being free from measurement errors if its occurrence had been replicated in at least one more patient and in a separate study. Eighteen more categories were occasionally tested but these appear not to be present among impairments: Cities, Countries, Crime, Earth formation, Geographical features, Large man-made objects, Numbers, Personal items, Science, and Shapes. The category ‘Famous persons’ was deemed not to match with Humans on grounds that it represents knowledge of specific individuals rather than a semantic class of objects (see Section 4).

According to the original sources, the patients’ mean age was 51 years (standard deviation 18.38, with 8 cases of missing data); 76 were males and 38 were females (7 cases missing). The etiology and anatomical regions of damage were reported in all patient cases (N = 121). The most widely reported etiology was Herpes Simplex Encephalitis (40 cases) and cerebrovascular accidents (27 cases). There were also patients with semantic dementia (11), traumatic brain injury (10), Alzheimer’s disease (9), cardiovascular disease (7), Closed Head Injury (3) and other neurodegenerative diseases (3) (for details of the remaining cases, see Supplementary material, supplement 1).

2.3. Conceptual content of the matched and unmatched categories

Table 7a lists the category-specific impairments (with at least two independently reported cases) and the matching linguistic classifiers. Table 7b lists classifier domains for which we found only 1 reported case of impairment but that would have matching linguistic classifiers. Table 7c lists linguistic classifiers for which we failed to find a matching category-specific impairment for the same semantic class.

The following elaborates on the semantic category terms for the two types of data, presented in short form with exemplifications.

Abstract may refer to properties (evil, weakness), intangibles (melody, state of mind), or verbal nouns (being a teacher, kingship). These concepts are not semantically coherent, but classes may be semantically motivated internally. For example, abstract notions may be semantically associated with non-containable or uncountable substances (particle substances: dust; thick liquids: saliva, honey), as in Swahili class 11/14 (Contini-Morava, 1997). In impairments, abstract refers to abstract nouns, tested e.g., by finding a synonym of an abstract word (“triumph” – “success”) among abstract distractor words (patient EC; Carbonnel et al., 1997). Among the above categories, the domain of abstract concepts is maybe the most difficult to compare. It is often treated as homogenous, however, several studies have shown that not only do abstract concepts differ from concrete in terms of scales along concreteness, context availability and imageability (Schwanenflugel and Shoben, 1983), but has an internal structure and can be divided in subtypes. For example, Caramelli
Table 7a
Conceptual content of the matched categories (N = 1) in Classifiers and semantic Impairments under the headings 'Classifier domains' and 'Impairment domains', with example of language/case in the rightmost columns. Key references for Tables 7a–7c are in the Supplementary material, supplement 2.

| Semantic category | Classifier domains | Language examples | Impairment domains | Patient examples |
|-------------------|--------------------|-------------------|--------------------|------------------|
| Abstract concepts | Properties (evil, weakness, human nature, manliness, intangibles (melody, state of mind, kingship), sensory qualities (sweetness, pain)) | Zulu | Abstract nouns. | KE |
| Animals | Animals in general or subgroups (domestic, pets, horses, pigs, dogs). | Malay | Animals in general (domestic, pets, amphibian). | FM |
| Aquatic animals | Fish, more rarely other sea animals (sea anemone, snakes). | Mandarin Chinese | Fish and molluscs; Reptiles and batrachians (alligators, frogs, salamanders); 'Water animals' creatures' (e.g., whale, lobster, crabs, turtle). | PS; KE; ER |
| Avian animals | Birds; in one case also mosquitoes, female flying birds. | Boro-Garo | Birds (e.g., duck, eagle, ostrich, owl, peacock, penguin, rooster). | LH; PS |
| Body parts | All types of body parts, vital (eye, heart), for sexual reproduction, extremities, paired/non-paired. | Dongo-ko | E.g., hand, finger arm, elbow, wrist mouth, lips, ears, nose, stomach, belly, toes, knuckle, foot, legs. | KE |
| Buildings | Buildings/houses/rooms, dwellings incl. habitable caves. | Burmese; Yidiny | Famous buildings/monuments, e.g., Empire State, Statue of Liberty; accommodation, e.g., cottage, palace, house, hotel. | FB; Emma |
| Clothing | Garments (upper, lower), clothes, cloth, footwear and hats often separate. | Burmese | Clothing, (e.g., jacket, blouse, pants, short, tie, vest), includes personal accessories (watch, ring, belt) and footwear (boot, shoe) and headwear (hat, cap). | SE |
| Color | Color, light (e.g., palm frond torch); things that differ in color (e.g., cloth, dog breeds). | Nasioi; Tepehua Huehuetla | Color knowledge for biological items; identify/name color of e.g., animals, fruits, sea, steak. | ER; CH |
| Dogs | Dog class; canine, incl. dingo. Positive and negative feelings; state of mind/feelings | Cahuilla | Dog breeds | BD |
| Emotions | Positive and negative feelings; state of mind/feelings | Vietnamese | Types of emotions: happy, tired, greedy, afraid, angry, sad. | YOT |
| Food | Food/dishes; flesh food, vegetable food, cooked- and raw food; starch food. | Kalai; Lama Lama; Japanese | Manufactured food items; solid edible substances (e.g., Nutella cream, ground pepper, cakes, bread) | RS; MU |
| Flowers | Flowers. | Mixtec | Flowers (e.g., rose, crocus, thistle, daffodil, carnation, buttercup). E.g., banana, lemon, orange, cherry, strawberry. Mostly tested together with vegetables. E.g., asparagus, lettuce, carrot, artichoke. | NR |
| Fruits and vegetables | Fruits; single or in bunches, nuts and coconuts, may be merged with vegetables or typical shapes (round, long). Vegetables; root-, round/head/-clustered-, vegetable food. Sometimes with fruit. | Bajau; Cahuilla Vietnamese; Wardaman | Manufactured food items; solid edible substances (e.g., Nutella cream, ground pepper, cakes, bread) | LA |
| Furniture | Furniture; - with 'limbs'; sets of furniture; benches, smoking racks, beds; tables/chairs. | Burmese | Furniture (e.g., table, bed, chair, sofa, desk, dresser), indoor appliances (lamp, clock, television). | EA; YOT |
| Insects | Insects (no subdivision); ants. | Boro-Garo | Insects (e.g., butterfly, ant, bee, beetle, caterpillar, fly, grasshopper, ladybird); spider. | NA; TU |
| Liquids | Water, fluids, liquids, drinkable liquids. | Q’anjob’al; Mokilese | Different liquids, e.g., olive oil, alcohol, drink. | MU; JBR |
| Materials | Wooden things; stone and things of metal; clay/soil, or fiber objects | Q’anjob’al | Wood, glass; non-edible materials of sensory quality. | MU |
and Setti (2005) examined the four subdomains cognitive processes (e.g., thought), emotions (e.g., fear), nominal kind (e.g., error) and states of the self (e.g., childhood). A special status for emotion words were suggested by Altarriba et al. (1999), since they were judged to be significantly less concrete than abstract words but context availability was still lower than that of abstract words, which, if context availability is a criterion for abstractness rather would make them more abstract. At the other end were they considered more imageable, which pulls in the direction of concreteness (Setti and Caramelli, 2005). Not only should researchers be aware of structural subdomains within abstract concepts, but also construct better sets of stimuli.
Table 7c
Classifier domains with no matching impairment for the semantic category, with example of conceptual content in classifiers under heading ‘Classifier domains’ and language cases in last column.

| Semantic category | Classifier domains                                                                 | Language examples |
|-------------------|-------------------------------------------------------------------------------------|-------------------|
| Books             | Books, bound volumes, notebooks, photo albums, magazines.                             | Japanese          |
| Decoration        | Body paint/ornaments, jewelry, garlands, personal titles.                            | Mokilese; Ponapean|
| Fire/light        | Fires, lightning, fluorescent, oil and electrical lamps, lustrous objects, fireflies.| Jacaltec; Chontal |
| Human             | Humans of either sex.                                                                | Assamese          |
| Human females     | Human female; individuals with female properties.                                     | Anindilyakwa      |
| Human males       | Human male; human male and male properties/activities.                                | Baniwa            |
| Kinship           | Blood relations (age-related, sex-related).                                          | Jacaltec          |
| Natural places    | Way, path; groove, garden plot; field, valley; steep incline, hill; reservoirs, lakes; locations. | Tuyuca            |
| Plant parts       | Branches and twigs, leaves, stalks, seed, roots and tubers.                          | Korean            |
| Shapes            | Long, flat, 2:3D round, cylindrical and curvilinear shapes of artifacts. Metaphorical shapes of humans. | Ojibway and Cree; Japanese |
| Social rank       | Honorifics vs. lower rank (age-related, religious, profession).                      | Puluwat           |
| Speech            | Speech, talk, language; word, syllable, brief speech, sermonette; oral narrative.    | Nasiol            |
| Valuables         | Precious items, valuable possessions including live stock, coins/money.               | Raga (Hano)       |

The animal domain has been widely used generically, to comprise all types of animals, but certain subdivisions may occur. One partition can be based on epistemological and habitat criteria: Terrestrial animals vs. Aquatic and Avian animals occur with separate classifiers and as separately impaired categories. Aquatic are mostly fish in both data sets, but classifiers may include squids/cuttlefish (Chinese) and impairment stimuli also include reptiles and batrachians. Avian animals are birds in the language data, in one case also includes other flying animates, like mosquitoes. In impairment studies, most avian animals were non-prototypical birds that could not fly (e.g. ostrich). Another division depends on the emotional relationship and purpose of use that the animal has to humans. The Baniwa relational possessive classifiers distinguish between animals that have an intimate from those that have a more random relationship to the owner (Aikhenvald, 2000: 143). Palikur classifies pet/domestic animals differently from animals caught for food, e.g., gi-pig pewru ‘my PET dog’ vs. nu-win arudiki ‘my CATCH tapir’ (Aikhenvald, 2000: 142). Silveri and Gainotti (1988; discussed in Hillis et al., 1990) reports a ‘semantic memory’ patient, AL, who is more impaired for wild than for domestic animals. Possibly, this is rooted in familiarity or differences in emotional ties as the type of distinction that underlies the known cases of impairment for dogs (Wilson, 1997). On similar grounds, horses have their own special classifier in Chinese, and elephants in Bengali. Divisions therefore do not seem to run solely along epistemological divisions based on habitat (air, land, water) or visual appearance.

Body parts are frequent in classifiers and cover all types. If subdivided in classifiers, they pattern in paired vs. unpaired (e.g., in Car Nicobarese), vital body parts (in Vietnamese: eye, heart), body parts for reproduction (in Enga), or body part extremities (in Ponapean). It could be argued that this category can further fractionate into further body parts impairments, since a study by Laiacna and colleagues (Laiacna et al., 2006) attested a lexical-semantic deficit of body parts that was most severe for limbs at 60.6% (arm, fingers, elbow, wrist, hand leg ankle, foot) and less severe at 89.3% for non-limbs (lip, eyebrow, nose, teeth, neck, breast, back, belly, buttocks, eye, ear).

Buildings in classifiers refer to any kind of human inside habitation, most frequently classifiers for houses (e.g., Khmer) and for rooms (e.g., Japanese), or may span all types of buildings, e.g., houses, monasteries, royal buildings (in Burmese), or more abstractly to dwellings (in Ponapean), shelter (in Motuna) or anything ‘habitable’ (in Yidiny), including habitable caves different from other things made of stone (Aikhenvald, 2000: 320).

Clothing comprehend lower and upper garments in both sets, but includes head- and footwear in impairment studies, which may be separate in classifiers (in Chinese), and personal accessories, which are excluded from clothing classifiers.

Color is barely attested in classifier languages and refers to a combination of color and luminosity (in Nasiol) or classifies things that differ in color, e.g., cloth or dog breeds. In studies of patients, color as part of object knowledge is typically impaired for one semantic category but spared in another; it can also be impaired as pure color knowledge (names of colors). Material often refers to wooden things, and hard things group together in classifiers, e.g., stone together with metal, and wood/glass was similarly impaired simultaneously. Material classifiers are often derived from their natural object noun; wooden < tree, fibrous < plant.

Dogs classifiers may elect domestic pet dogs (in Cahuilla) or may include other canines as well; in Ngan’gityemerri classifier wu- is used for ‘canine’, e.g., Wu-pidirri ‘CANINE-dingo’ (cf. Aikhenvald, 2000: 317, 394–395). Likewise, patients can be specifically impaired for dog breeds.
*Emotion* in classifiers may refer to types of emotion, e.g., positive vs. negative feelings (e.g., Vietnamese), or be affiliated with non-bounded substances like emissions and fluids (e.g., Magar). In impairments, emotions refer to types of emotion (Warrington and McCarthy, 1987).

*Fabrics* classifiers refer to cloth and things made of cloth, e.g., a shirt (in Tariana). In impairments, fabrics are various types if cloth, such as wool, cotton, linen, nylon, velvet, silk, denim, etc.

*Flowers* occur with their own classifier and can also be impaired as a category, comprising wild and cultivated variants (e.g., rose, crocus, thistle, daffodil, carnation, buttercup).

*Food* in impairment studies refers to ‘manufactured food’, and in one case a set of ‘solid substances’ like Nutella cream and ground pepper were tested for sensory qualities (Borgo and Shallice, 2001). Food classifiers typically comprise all types of food, but may subdivide between raw and cooked food (in Puluwat), and commonly in Australian Aboriginal languages between vegetable and flesh food.

*Fruit* classifiers generally comprise all kinds of fruit, sometimes also nuts or coconuts (in Kiriwina). Arrangement is a relevant property for fruit classifiers (single, in bunches), as is its shape (extends to other round objects). The fruit stimuli in patient studies might contain berries, and were for the most part merged with *vegetable* stimuli. Languages may have a classifier for fruit only (in Mayali) or separate classifiers for fruit and vegetables (in Gumuz) or for vegetable only (in Cantonese). As mentioned, some impairment studies did not distinguish precisely between *food* and *fruit/vegetables*. While these differences clutter the comparison across studies, it may be interesting to note that the same inconsistency exists in classifier systems; that is, there may be single classifiers for ‘fruit food’ (in Macushi), for ‘vegetable food’ as opposed to ‘flesh food’ (in Emmi), or a shared classifier for fruit/vegetable/vegetable food (in Apalai). Vegetables in both data sets comprise root and above ground vegetables, but languages may have special classifiers for roots or tubers. As for fruit classifiers, they are sensitive to arrangement, whether as separate or in clusters.

The *furniture* category overlaps in the two sets with common indoor objects like tables, chairs, beds, but stimuli used in tests of patients also include appliances that are less furniture-like. Classifiers may focus on visual appearance of the furniture (in Thai: furniture that has legs, derived from body/animal). Both types of *weapon*, hunting and war weaponry, are represented in both sets, though arms for hunting are more common in languages than war arms. Shape is prominent in the classifier hunting weapons and may extend to other long shapes.

*Insects* are rarely subdivided in classifiers, but in Yidiny ants have a special term. Semantic deficit tests contain all types of insects, flying and crawling, as well as spiders.

*Letter* classifiers recognize letters of the alphabet and letter impaired patients have lost the ability to recognize and name uppercase and lowercase letters.

*Liquids* in both types of data identify knowledge of their fluidity and function as something drinkable.

*Material* is listed in Aikhenvald (2000: 338) as one of the “universal natural categories” but often co-occurs with other semantic bases like arrangement or quantity, and it can be hard to determine which is primary (ibidem: 292). Interestingly, children tend to use material as an organizing feature of classifiers much more than adults do (Carpenter, 1992: 142; Aikhenvald, 2000: 421). In classifier systems, material and consistency (flexible vs. rigid/hard) are sometimes aspects of the same thing, and material can become less significant than consistency (e.g., when ice in Jacaltek is classified with the *rock* classifier).

In a few languages, manual *musical instruments* are classified with tools (in Burmese), although more rarely musical instruments have a separate classifier (in Panare).

*Occupation* was treated as ‘properties of humans’ in both types of data. In Luganda, a special set of derivational noun prefixes associates grammatically to the human classifier. Semantically these denote human nouns depicting humans’ professions, proper nouns, kinship terms, and titles (Ferrari, 2005: 189–190). In Chinese, the honorific classifier *méi* for humans contains mostly people of various occupations, but also kinship terms, i.e., properties of humans. In the impairment literature, deficits associated with face-to-name matching, occupation is one of the commonly impaired properties of famous people (Haslam et al., 2002; Crutch and Warrington, 2004), along with nationality, names, and dead/alive status (Miceli et al., 2000; Ellis et al., 1989). Other human properties present in classifiers are *man, woman, social rank, kinship*, none of them attested in impairments.

*Plant* classifiers encompass trees as well as plants and bushes, more rarely grass and herbs, but in the impairment tests plants were rarely tested separately. If they did, these included ‘trees and plant parts’. *Plant parts* are frequent as independent classifiers as leaves, stalks, roots, seed and trunks.

*Small, manipulable objects* refer to classifiers that are designed for objects that can fit in various handgrips; whole hand grasp or pinch grip (in Japanese, Chinese, and Vietnamese), paralleled as a semantic deficit in patient YOT (Warrington and McCarthy, 1987).

*Time unit* classifiers single out time spans, such as days or nights (in Satawalese). Patients can be impaired for specific time units, either seconds, minutes, hours, days, months, or years, thus a wider type than classifiers, including ‘artificial’ time units measurable by the clock.
Tools are typically hand-held, and classifiers categorize them for this manual property or, more rarely, point to the efficacy of their working parts (bladed instruments in Gorontalo). They are used in household cooking or cleaning, agriculture or carpentry.

Vehicles refer to motor vehicles in both sets, but can also contain non-motor transport. Aerial vehicles are not separated in impairment tests, but may have separate classifiers (in Japanese).

Water vessels more often group apart from land vehicles in language, and boat types are also attested as impairment.

Wild animals are rare but Rengao classifies ‘wild beasts’. A patient had a deficit for wild as opposed to domestic animals. We also find special classifiers for domestic animals (in Cayuga and Cora).

2.4. Limitations to the data sets

There are a number of limitations to the data sets that may constrain what conclusion can be drawn from them. One caveat of our data is that studies often tailored the stimuli and tasks to each patient and were not necessarily driven by a need for standardization (although most studies did use standard test batteries and stimuli from Snodgrass and Vanderwart, 1980). A further caveat is that the “corpus” of described specific semantic deficits is not comparable in depth or breadth to that of human languages. In fact, a systematic survey on all neurological patients in terms of their conceptual knowledge is unrealistic in practice and the available data are so far limited to a little more than a hundred individual cases. In addition, domains of semantic knowledge included in the formal tests may have so far represented only broad aspects of knowledge and possibly missed some domains. Another limitation we face is that all of the neuropsychological studies have taken place within the academic and medical systems of Western societies (Europe and North America), while neuropsychological data from classifier language speaking populations that could have provided complementary information on the distribution of categories in semantic deficits are still lacking. Nevertheless, a few studies on language impairments like aphasia (Thai: Gandour et al., 1984, 1985; Chinese: Tzeng et al., 1991) constitute an exception from the general situation that studies on neuropsychological data from linguistic societies where the target classifiers are present (e.g., for animate things) is lacking. We are aware of but did not include these aphasia studies since they followed testing procedures different from the main stock of category-specific impaired patients.

Furthermore, a previous unbalanced testing in impairments is that the neuropsychological data represent deficits for some categories abundantly but these appeared for only a few patients. That is, neuropsychologists might have devoted different amounts of attention to the various categories. For example, ‘musical instruments’ became a leitmotiv in this research area, perhaps because of the initial, surprising, co-occurrence of this class with impairments for living things (e.g., animals; Warrington and McCarthy, 1987; Turnbull and Laws, 2000). As a result, the ‘musical instruments’ category has been included in 37 studies and found to be impaired in 26 cases. But it remains possible that several other categories might have received less attention and consequently tested fewer times (e.g., liquids = 5 times). Thus, there is a risk that the available data set may be limited in semantic scope and biased toward some categories. Table 8 lists the number of cases in which a category was impaired together with the number of times it was specifically tested.

This imbalance seems not to have troubled several of the neuropsychologists.

Moreover, one possible source of error lies in the variety of testing procedures and the types of specific behavioral tasks, selected stimuli, utilized in the tests. Some studies did test several separable categories but did not report the responses to the subcategories (e.g., Gonnerman et al., 1997, included the categories furniture, vehicle, weapons and clothing, but presented numerical data only for the total as the superordinate of ‘artifacts’). Other researchers (e.g., Warrington and McCarthy, 1987) present a far more fine-grained categorical organization (i.e., patient YOT who was classified as generally impaired for inanimate objects was evaluated for particular subordinate classes). Many reports grouped items in the commonly tested subcategories (e.g., animals, body parts, vegetables, fruits, tools, furniture, vehicles) into higher-level superordinate categories of “biological” vs. “artifact”, sometimes referred to as “living things” vs. “non-living things”, making the claim that such a superordinate level actually best defines the semantic impairment. In these studies, non-living things most often include tools, vehicles and furniture, and less consistently clothing and kitchen utensils. However, there appear to be intermediate zones between these biological vs. non-biological superordinate categories. The subcategories “food” and “body parts” have been in particular the focus of debate since their isolated impairment violates the common sense, superordinate, division between living/non-living things (Capitani et al., 2003).

Finally, there have been inconsistencies in classifying some subcategories within the superordinates, since some researchers (e.g., Warrington and Shallice, 1984; Sirigu et al., 1991; Sheridan and Humphreys, 1993) have used the term ‘food’ to include ‘fruit and vegetables’, although these can be dissociated (Farah and Wallace, 1992).

Although, the above list of limitations may engender the expectation that it may be hopeless to gather sufficient evidence about commonalities between impairments and classifiers, it will be evident that despite the ‘noise’ and likely presence of artifacts a clear and systematic pattern emerges when comparing the available evidence.
Table 8
Semantic categories under investigation in category-specific semantic impairment studies, showing number of cases showing presence of an impairment or not and the number of studies that included the category.

| Category               | Impaired | Spared | Times tested |
|------------------------|----------|--------|--------------|
| Animals                | 70       | 19     | 89           |
| Fruits and vegetables  | 51       | 12     | 63           |
| Vehicles/transportation | 15       | 32     | 47           |
| Tools/kitchen utensils | 23       | 28     | 51           |
| Furniture              | 16       | 22     | 38           |
| Musical instruments    | 26       | 11     | 37           |
| Clothing               | 9        | 20     | 29           |
| Food                   | 17       | 10     | 27           |
| Colors                 | 9        | 13     | 22           |
| Avian animals          | 15       | 0      | 15           |
| Insects                | 10       | 5      | 15           |
| Flowers                | 12       | 2      | 14           |
| Plants                 | 10       | 4      | 14           |
| Buildings              | 5        | 5      | 10           |
| Weapons                | 5        | 3      | 8            |
| Aquatic animals        | 6        | 1      | 7            |
| Abstract words         | 2        | 4      | 6            |
| Liquids                | 5        | 0      | 5            |
| Emotions               | 2        | 2      | 4            |
| Water vessels          | 3        | 1      | 4            |
| Dogs                   | 4        | 0      | 4            |
| Materials              | 3        | 0      | 3            |

3. Results

There was a set of matched and a set of unmatched semantic categories (cf. Tables 7a and 7c). Fig. 3 shows the scale of these matches and differences.

The categories that found no counterpart in category-specific semantic impairments were Books, Decoration, Fire/light, Fruits, Humans, Human females, Human males, Kinship, Nature/location, Plant parts, Social rank, Speech, Shapes (flat, irregular, long, round/curved, square, tiny round, size) and Valuables. Among these, Humans (172 incidents) and Shapes (altogether 228 incidents) were particularly frequent in Classifiers.

For the matching categories, since we predicted that if there exists a semantic category that is affected in cognitive impairment, this category will be likely to exist in some classifier language, we computed the (one-tailed) probability of obtaining exactly 30 instances (or more) of matching impairments and classifiers out of the 43 identified semantic domains. Assuming that chance co-occurrences have equal probability (i.e., \( p = 0.5 \) for observing or not a match), our prediction is confirmed since the obtained probability was \( p = 0.004 \) or a highly unlikely outcome by chance co-occurrences and the one-tailed probability of exactly or greater than 30 instances is \( p = 0.007 \).

An intriguing finding was also that a positive relationship emerged between the frequency of a certain type of impairment observed in patients and the frequency with which this category is also found in classifier languages. Although it is debatable whether such a relationship can be accounted by positing universals in cognition, we would like to suggest that such a positive and significant relationship is unlikely to derive out of noise or chance observations. It seems plausible that certain semantic categories may emerge more consistently than others in both knowledge and language, due to differences in their relevance or salience at the cultural or even evolutionary level.

As shown in Fig. 4, we performed a linear regression analysis of the relationship between the frequencies of occurrence of a Classifier and for at least two independent neuropsychological reports \( (N = 2 \) to reduce the likelihood of counting a single chance event) of impairment for the same semantic category. This analysis yielded a significantly positive relationship between the two, \( r = .542 \) \( (r^2 = .294) \), slope coefficient \( (b) = 1.2 \), \( t(28) = 3.4 \), \( p < .002 \). In particular, we seem to have exposed commonalities between impairments and classifiers at an “intermediate” semantic level, where classes tend to be rather specific (e.g., fruits and vegetables, insects) than high-level superordinate domains (e.g., living, inanimate) and that some commonalities occur even at the “basic level” (e.g., dogs).

Moreover, both in neuropsychology as well as in language studies, scholars have particularly focused on the superordinate bifurcation between animate vs. inanimate, which could have profound implications for the grammar of most languages (Frawley, 1992). Neuropsychologists have proposed a similar animate and inanimate distinction to
Fig. 3. Incident rates of all registered categories in Classifiers (blue color, left columns) and Impairments (red color, right columns). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 4. Scatterplot of the frequencies of category-specific impairments in western neurological patients and documented classifiers for the same category in non-western languages. The interpolating line is the linear regression and each dot represents an overlapping category (N > 1) in the linguistic and neuropsychological corpuses. For illustration, we have labeled a few categories types (e.g., 'Animals', 'Tools').
characterize robust ‘double dissociations’ within category-specific semantic deficits (Caramazza and Shelton, 1998). However, recent neuropsychological evidence suggests that semantic impairments may also group reasonably well according to a tripartite distinction between two types of biological domains (Biological Animal or Animals; Biological Inanimate or Plants) and the non-biological Inanimate (e.g., Manmade objects). This is a difference that goes beyond the ability to move. The difference regards a difference in sentence and perhaps awareness and the fact that animals have a highly complex sensory nervous system while plants have a very basic ability to sense.

In Table 9, we show the results grouped according to this tripartite distinction, by grouping the specific impairments and their matching classifiers into three sets. Thus, in the present context, the label ‘Biological Animal’ refers to classifiers and patients presenting some of these categories: Animals, Dogs, Aquatic animals, Avian animals, and Insects. Instead, ‘Biological Inanimate’ or ‘Plants’ includes classifiers/patients in the general category Plants as well as the subcategories of Plant parts, Flowers, Fruits and Vegetables. Finally, the ‘Inanimate’ label gathers the documented instances for Tools in general, as well as Musical instruments, Furniture, Clothing, Materials, Vehicles, Water vessels, Weapons and Buildings.

In order to test the hypothesis that there are strong commonalities in the two domains of language and cognitive deficit, we ran a Chi-square analysis on the frequencies of the tripartite superordinate categories (see Table 9) for both impairments and classifiers. We found that the frequencies of these superordinate semantic classes compared to the related impairments had no significant difference, Chi-square (2) = 2.95, p = .23, suggesting that the parsing of the semantic domains in the two corporuses occur along similar boundaries and with similar probability.

Similarly, we can entertain the proposal for a bifurcation of category-specific impairments between Living things vs. Non-living things. A few languages (five) in our database used classifiers for animate beings together with plant life (Aceh, Comorian/Maore, Ku-Waru, Ma'a/Makhwa and Runyoro-Rutoro), which therefore appear to correspond to the overarching category of ‘Living things’. However, we have evidence for only one ‘Non-living things’ classifier (Yucatec Maya) which is used for ‘all things non-human, non-animal and non-plant’. Interestingly for Impairments, we have several reports of patients who had deficits for animals together with plant life (but not for non-living things), as well as patients with the opposite pattern of deficits for Nonliving things (as defined above). However, we had to exclude 29 patients because they did not have specific impairments in one domain but also within the opposite domain. The counts for impairments for Living vs. Non-living things necessarily differ from those in Table 9 that grouped subcategories within the animate and inanimate domains. Specifically, we identified 49 cases that had deficits for Living things vs. 17 cases with deficits for Non-living things. Again, we put to test our prediction of commonality between the impairments and classifiers domains and compared these frequencies with Chi-square (1) = 0.24, p = .62, suggesting that these dichotomous semantic domains occur with similar probabilities in languages and neuropsychological cases.

We also note that the neuropsychological evidence suggests that the more specific impairments tend to co-occur, so that their associations tend to constitute what appears to be a higher-level semantic deficit within a superordinate semantic domain (e.g., non-living things). We formally tested this possibility by applying the analyses of co-occurrence patterns as developed by Griffith et al. (2016).

The results of co-occurrence analyses (displayed here in Figs. 5 and 6) reveal which of the observed co-occurrences are significantly greater than expected (positive association), significantly small and less than expected (negative association), or not significantly different and approximately equal to expected (random association).

Fig. 5 reveals a heat map of the significant associations for Living things and the subcategories of Animals, Fruits and Vegetables, and Flowers, and significant dissociation from Body Parts. In contrast, impairments for Non-living things dissociate significantly from Animals, Food, and Fruits and Vegetables, while showing no significant association with any of the subcategories. Several of the intermediate categories tend to co-occur with other subcategories (e.g., Animals with Fruits and Vegetables; Food with Color and Flowers; Avian Animals and Musical Instruments with Insects; Furniture with Vehicles and Tools).
In Fig. 6 we show an analogous co-occurrence analysis for classifiers. Nota Bene: in this analysis some categories (e.g., Colors, Living things and Non-living things) are absent, since the algorithm by Griffith et al., (2016) removes cases with <1 co-occurrence in the dataset from the analysis. The heat map shows several significant associations between subcategories (e.g., Animals with Plants and Shapes; Humans with Buildings, Kinship, Tools, but also Fruits, Animals and Plants).
4. Discussion

Semantic category dissociations have been accumulating in neuropsychological reports of (mainly European) patients with impairments for specific semantic classes. Independently, linguists have thoroughly documented semantic classifier systems across numerous and unrelated languages. By comparing data about the nominal classifier frequencies from linguistic studies with frequencies of category-specific impairments, we have uncovered substantial overlap between them, which suggest a common structure for thoughts and words or, in general, for human cognition.

Indeed, from the outset, we had expected that if there exist a semantic category affected in cognitive impairment, then this category will be likely to exist in some classifier language. We also found that there was a positive relation between the frequency of a specific impairment observed in patients and the frequency with which this category appears in classifier languages. Despite the classifiers data set is considerably larger than the category-specific impairments set, the frequencies of classifiers in the linguistic set were able to predict the relative frequency in the neuropsychological literature of reports documenting a related specific semantic impairment. In other words, despite the presence of divergences between the two corpora, we documented recurring patterns and striking commonalities in frequency of occurrences in the two data sets, which we believe point to domain-general constraints on how both patterns impairments and classifiers’ uses have emerged.

Is there reason to expect that a match of frequencies in classifiers and impairments should be caused by common cognitive constraints? Potentially, the causes of the distributional variance of category-specific could have to do with susceptibility to injury by etiology and the frequencies of semantic categories recurring in classifiers systems will have its own causes, for example usage frequency, cultural influence or habitat. A potential source of variation in the semantic impairment data may lie in their various etiologies, which could have differential impact on modality-based memory systems. Indeed, it has been suggested that the incident rate of specific impaired categories is linked to etiology (Capitani et al., 2003) and the location of the lesion within the brain (Damasio et al., 1996; cf. also Caramazza and Shelton, 1998; Brambati et al., 2006 and Campanella et al., 2010).

We also believe that the relationship between these two different sets of observations is unlikely to be due to chance observations, pure variability and noise, or biased data samples. Further, we note that the linguistic structures in many of the languages here reviewed are independent of each other, since they reflect human populations as wide apart as Asia, Oceania, Australia, Africa and the Americas. Hence, we can hardly attribute the commonalities in their grammatical structure to diffusion of linguistic features through languages’ contact. Furthermore, considering that all the existing cognitive impairments occurred within linguistic groups that actually lack these classifiers in their grammar, these regularities across domains of study converge on the idea of some underlying universality in cognitive structure.

What seems to emerge in the present comparison is the primacy of some conceptual kinds and that there may be a finite list of such fundamental cognitive kinds. Some neuropsychological accounts have proposed that the neural representations of knowledge may dissociate into specific semantic impairments as a result of damage to modality-specific subsystems (visual, tactile, etc.; Gainotti and Silveri, 1996; Gainotti, 2015b disrupting bundles of properties associated, in different degrees, with a specific concept. For instance, knowledge of animals but not of artifacts might strongly depend on knowing their shapes and therefore the features encoded by the visual system may be essential for concepts about living things in general. In particular, the ‘sensory-functional’ account of category-specific impairments (Warrington and McCarthy, 1983, 1987; Warrington and Shallice, 1984) relates modality-bound properties and functional properties (i.e., those established through human-object interactions or affordances) to different parts of the brain; hence making them prone to dissociate after brain damage. According to current models (e.g., Mahon and Caramazza, 2009), several semantic categories are supported by exclusive (differential) brain areas and knowledge about these categories can be selectively lost when these areas are focally damaged. Caramazza and Shelton (1998) suggested that semantic categories are organized in the brain according to ‘object domains’, as a result of ‘evolutionary pressure’ and not just along the brain's maps of perceptual modalities and action control. That is, biologically relevant demands could have shaped the human brain to select specific categories essential to survival (adaptive costs and benefits) and dedicate closely interconnected neural networks to the representation of related knowledge; namely, biological things like animals or plants (relating to their potential sources of danger or nourishment), tools or manmade objects (relating to their adaptive roles of controlling and modifying the environment), ‘conspecifics’ (for cooperation, kinship). Given the evolutionary aspect of this model, it is consequential that such a conceptual structure would appear to be highly similar across humankind and emerge in different aspects of cognition.

If language is seen broadly as ‘a cloak following the contours of thought’ (Brown and Lenneberg, 1954), the knowledge of such ‘natural kinds’ (e.g., biological species) could be at the origin of classifiers (Berlin, 1972; Downing, 1984). Moreover, if properties of language can provide converging evidence and therefore help to constrain the proliferation of neuropsychological models and identify an optimal account of neuropsychological organization, it would seem that a ‘sensory-functional’ account of category-specific impairments receives little support in the linguistic domain. In fact, for
classifiers, perceptual attributes or modalities would seem just as essential for artifacts as for biological kinds. For inanimate entities, a physical shape can in many cases be the prominent semantic basis for category membership and category extension. Thus, many artifacts can be classified according to the common shape and dimension characteristics from the one-dimensional to the two-dimensional and 3D (Keller, 1955). Extendedness-in-space criteria, e.g., horizontal vs. vertical, size and the way an object differentiates its inside from its outside (e.g., rings vs. holes), or how and object is temporarily arranged into a certain shape are also important (coiled, strung together, in a bunch; Aikhenvald, 2000: 272–274). For example, numeral classifiers are dispersed in semantic space according to how the human body is capable of physical interactions with objects, either manually and dividing into hand-shapes ‘pinch-grip’ and ‘whole hand grasp’ on the one side, or otherwise for large sized objects (which have for example classifiers in Japanese, Chinese and Vietnamese; Tran, 2011). Although knowledge in classifiers appear to be based on sensory and motor information derived from vision, touch, etc. (Lee, 1987), they recur as “kind” concepts in most systems. A divide in classifier systems runs between kinds (unit level) and configurations (extracted qualities of objects; Denny and Creider, 1986). Kinds may describe the animate domain (humans, animals) or the living but inanimate domain (plants, fruits and vegetables) as well as inanimate objects (artifacts; tools). Configurational classes can distinguish extended from non-extended space, interiors, dimensions, shapes, and paths (e.g., in Burmese, the inanimate classifier ‘si’ is used for ‘lower things that move in straight lines’, which can include both vehicles and moving animals, e.g., when hunted; Becker, 1975). Exceptionally in some languages, animals are classified according to their shape: for instance, in Baniwa (Arawak; South America), ‘humans’ are classified according to animacy but ‘animals’ based on their shape (e.g., jaguars are classified as vertically shaped and birds as concave; Aikhenvald, 2000: 272, 385).

Remarkably, classifier systems present an analogous ambiguity to ‘Body parts’ as neuropsychological deficits since this class can be included in both the animate and the inanimate domains. However, animates (humans, animals) are classified by a salient body part (body, head), and inanimate objects are classified by a body part’s inherent shape (head > round; leg > long). ‘Food’ nouns obviously refer to non-living items and therefore considered as a low-level biological, life material/organic class. Many Australian languages share the feature of a ‘vegetable food’ class, typically encoded with an initial ma-, mi-, or m- prefix. Interesting for comparison with the semantic impairment cases, Gurr-goni classifies body parts with plants – in the ‘vegetable food’ class, containing ‘most body parts, dead bodies, and feces’ (Aikhenvald, 2000: 408), i.e., derived organic material. In several classifier languages, there are borderline classes based on animacy: e.g., complex motion patterns (in Vietnamese for kites), independently moving or acting body parts considered to be particularly ‘lively’ (Vietnamese: eye, pupil of the eye, heart, penis), or shape extensions based on biological form (Thai: ‘tua’ ANIMAL > furniture and clothes with ‘limbs’). These cases may suggest that both shape and motion are quite relevant tokens for determining animacy.

The co-occurrence analyses (Griffith et al., 2016) between specific impairments (Fig. 5) and classifiers (Fig. 6) also provided relevant information in relation to the considerations above, since recurring patterns or associations or constellations of categories within both domains revealed emergent higher-level semantic domains (e.g., non-living things). We observed co-occurrences that are significantly greater than expected (positive association) or less (negative association). Interestingly, for impairments the superordinate Living things significantly dissociated from Body Parts. Several of the intermediate categories tended to co-occur with other subcategories based on perceptual properties (e.g., Food with Color and Flowers; Avian Animals with Insects). Regarding classifiers, shapes were associated with the greater part of the categories, indicating that shape is important for living as well as non-living things. We observed significant associations between subcategories that seemed to relate to the social life and activities of our conspecifics (e.g., Humans with Buildings, Kinship, and Tools). Both Human males and Human females were significantly associated with Fire/Light but Human males dissociated from vehicles, marking a distinction between biological and non-biological motion. Most importantly is the fact that despite the linguistic data has more diversity and a larger scope than the semantic domains highlighted by the neuropsychological deficits, several of the associations appear to be common to both co-occurrence analyses (Animals with Plants; Body Parts with Tools).

Although we have stressed that classifier and semantic impairment data constitute entirely independent data sets, some aspects of the semantic grid observed in classifier systems may surface in non-classifier languages as well and, indeed, most clearly in the division between animate and inanimate entities. All languages would seem to mirror ‘animacy’ in some aspect of grammar, even in the languages spoken by the patients in the impairment dataset (mainly English, but also native speakers of Italian (N = 18), French (N = 11), German (N = 2) and Gaelic (N = 1). However, these systems are only minimally animacy based. For example, the Italian language is based on a minimal gender system with two genders (visible as concord within the constituent: la mia bellissima macchina ‘my beautiful car’), but unlike natural (semantic) gender the Italian classes are not primarily based on the biological sex of the noun’s referent (Bassetti, 2007: 253). Whereas in natural gender systems there is correspondence between a grammatical form and the sex of the signified, grammatical gender systems like the Italian frequently assign nouns with asexual referents to the feminine and masculine classes (e.g., sedia ‘chair’ – is feminine, tavolo ‘table’ – is masculine). Moreover, the noun’s phonological form may take supremacy over the sex of the referent also when these nouns are used for either sex in Italian, e.g., persona ‘person’ and...
oca ‘goose’ are assigned to feminine gender simply because of their common endings in –a. This clearly makes the Italian system only weakly semantic-based.

Animate characteristics in classifiers extensions from human/animate to inanimate/less animate classifier categories may help reveal what specific cognitive notions contribute to animacy. These cases may suggest that both shape and motion are quite relevant tokens for determining animacy. In Kirwina, the animal classifier is also used of spontaneously moving things. Another example is Swahili, where the characterization of nouns in Class 3 as ‘entities with vitality’ is meant to capture attributes of living things, but reserved for entities that are neither human nor prototypically animal (humans and animals have their own designated classes), e.g., powerful natural and supernatural phenomena (which act on and causally affect other entities, independent of human volition), human collectives and plants (units with ability to grow and reproduce, e.g., ‘city’, ‘beehive’), active body parts (ability to move), and tools that have movement as a salient feature (e.g., arrow, pestle, chopper); i.e., not self-propelled but must be set to move by a human agent (Contini-Morava, 1997; Lobben, 2012).

Animacy is clearly a basic cognitive divide in category-specific semantic impairments as well (Caramazza and Shelton, 1998), however certain categories can be impaired beyond the animate/inanimate divide. According to neuropsychological evidence, three categories can be impaired or spared beyond the animacy divide: while musical instruments and food can be impaired conjointly with living things, body parts can be selectively spared along with non-living things (Gainotti and Silveri, 1996; Mahon and Caramazza, 2003). Considering musical instruments, special classifiers for musical instruments are attested but not common. The possessive object classifier nlyén in Panare (Cariban; Venezuela) is used for musical instruments like the flute, guitar or violin. In contrast to the reported cases that musical instruments are conceptualized as living things, in Burmese and Thai, musical instruments are classified with other types of tools, i.e., artifacts. In Burmese, le’ can be used for hand tools and swords, but also for puppets and musical instruments, i.e., objects that are held. Remarkably though, tools are sometimes conceptualized along animacy scales. A typical meaning of tools in classifier systems is that they are potentially potent but inanimate and consequently dependent on an animate agent to be brought to action. For this reason, Akan musical instruments were in the ‘low power class’ together with physically or socially powerless humans (‘child’, ‘slave’, ‘servant’, ‘orphan’, less dangerous animals), contrasting with powerful beings in a ‘high power class’ (‘devil’, ‘god’, ‘master drummer’, ‘priest’, ‘elder’, ‘elephant’, ‘eagle – king of the air’; Osam, 1994).

A fundamental difference in classifiers and non-classifier languages is that there is no systematic semantic organization of noun referents. However, a common conceptual-semantic substratum may instead surface as selection restrictions on verbs (Wall, 1968), or selectional constraints (Resnik, 1996); the fact that verbs can be semantically sensitive to the nouns they co-occur with in a sentence. For example, a verb may require an animate subject (jump, run, see, hear) or animate subjects and objects (decapitate, castrate). Verbs may select specifically for human subjects and objects (marry, murder, ordain, kidnap, warn, advice), a human object (surprise, amuse), or subjects and objects that are inanimate (absorb, drift, entail). Others may require a concrete, physical object (chap, crash) or concrete subjects and objects (hit, build, weave). These cases likely derive from the same experiential bases as those that select for semantic domains in classifiers, but could reflect language-particular idiosyncrasies due to lexical specialization.

What the above discussion suggests is that certain semantic cores are present deeply in all human cognition but can surface also in minds who do not speak a classifier language. Moreover, the cross-linguistic variation of inventory size and semantic category types existing in classifier systems presents a parallel. Not all classifier systems actually express all of the same semantic bases. One on hand, one wonders whether a documented impairment category may actually reflect the constraints from the environment (physical and social) one habitually lives in, but also the sensory and motor apparatus of the human body. A loss of motion properties would seem to be the sole contributor to a patient’s impairment for animals (Garrard and Carroll, 2006). On the other hand, one could argue that the most general (ontological) categories could be evolutionarily built-in in the human brain reflecting mechanisms for survival. The ‘innateness’ would restrict itself to the constraints or “scaffolding” imposed by the human biology, including human brain structure supporting cognition. Christiansen and Chater (2008) have stressed that human learning and languages are intimately related in structure and it is likely that “language has been shaped to fit the human brain”. However, we note that some salient classifier categories were remarkably absent in the impairment data and that these would seem to have relevance for human survival; e.g., human males, human females, dwellings and locations, social relations and kinship, conspecifics. Other categories were represented in both data sets but are unlikely to have existed since the dawn of mankind; e.g., furniture, occupation, or vehicles, and it is still debated how ancient musical instruments’ making could actually be (e.g., Tomlinson, 2015). Similarly, Kemmerer (2017) draws the attention to a parallel between the semantic domains commonly occurring across noun classification systems and recent work that has been done in cognitive neuroscience on brain topography that could support a universal semantic grid in the domains of animacy, shape and related properties, size, constitution/material makeup and interaction/function. In neuroimaging studies, animals activate brain regions involved in form perception and biological motion, but also areas specific to face recognition, body knowledge and emotions when contrasted over tools (Martin, 2007). Brain topography along the ventral temporal cortical surface reflects a scale of gradient animacy with dedicated regions for higher animate (humans and chimpanzees), intermediate animate (types of
bird and fish), and low-animacy individuals (lady-bugs and lobsters) (Connolly et al., 2012; Sha et al., 2015). Notably, these findings were made with speakers of non-classifier languages, however it also illustrates the neural basis for how, in some of the classifier languages reviewed here, insects are considered animate and in others not. Kemmerer also draws the attention to areas that are relevant in classifier systems have not surfaced within neuroscience: sub-categorizations of people along the scales of sex, age, kinship and social rank, supposedly because they have not been thoroughly investigated. Coincidentally, none of these have shown up as impairments. Likewise, he points out that recurring shapes in classifier systems correlates with geons, simple shapes defined by largely the same properties as 2D and 3D shape classifiers (cylinders, bricks, wedges, cones, circles, rectangles and) and that when combined can explain visual object recognition of billions of real-world objects (Biederman, 1987). Moreover, a posterior to anterior axis along the brain’s ventral stream seems to be sensitive to shapes independently of semantic category (Bracci and de Beeck, 2016). Size usually clusters with shape and/or dimensionality, and hence we have classified size classifiers as a subtype of shape. We have argued that this is a category that cross-sections other categories, and this is further supported by neuroimaging experiments. Konkle and Caramazza (2013) showed that size interacts with animacy such that there is a tripartite division in the ventral stream between all animals whether big or small, and distinct regions for big and small inanimate objects. In this study, large animals like bears and giraffes were not anatomically segregated from smaller animals like rabbits and parrots. There are, however, classifier languages, e.g., Japanese, that have one classifier for big (too-) and another for small (hiki-) animals, the latter actually classifying rabbits. This is, then, not a perfect match across cognitive neuroscience and classifier domains.

As for material makeup, Kemmerer points to evidence from Jacobs et al. (2014) that certain cortical areas in both the visual and the somatosensory systems are engaged in a multimodal manner, including vision and touch, when objects' perceptual qualities are experienced, even if only one modality is involved. Jacobs et al. examined brain activation to photographs of materials consisting of wood, stone, metal and fabric surfaces. Three regions were involved in material categorization and in analyzing materials’ properties (supramarginal gyrus, and possibly postcentral gyrus and the cerebellum). Interestingly, the somatosensory cortex, primarily involved with tactile stimuli, was also activated during visual presentation of materials. This study revealed that certain brain regions are involved in the perception and categorization of materials, but is silent about which materials are grouped together. Hiramatsu et al. (2011), on the other hand, had subjects rate visual images of various types of materials. Superordinate categories emerged based on dichotomous adjective pairs like matte-glossy, dry-wet, cold-warm, soft-hard, light-heavy, elastic-inelastic and natural-artificial across the materials metal, ceramic, glass, stone, bark, wood, leather, fabric and fur. One set of materials clustered around adjectives simple, smooth, hard, cold, artificial and glossy and combined metal, ceramic and glass. Another set contained stones, bark and wood clustered around the qualities complex, rough, irregular and natural. A third cluster was composed of leather, fabric and fur and characterized as soft, elastic, warm and light. Their main finding confirmed the Jacobs et al. study that early (i.e., primary) visual areas correlate with image properties and material categories are instead handled by higher-order regions of the brain1 (the fusiform gyrus and the collateral sulcus; in Jacobs et al., the parahippocampal place area and visual areas V2 and V4). Thus, the semantic ratings correlated with material categorization and low-level visual image properties with activity in primary visual areas.

In classifiers, hard materials are often classified together. For example, in Jakaltec, the classifier ch’en is used for stones in the household (grinding stone, grinding roller, cooking stones), glass, metal, and ice (note that ice fits in with the inclusion of the adjective cold in the Hiramatsu et al. study). As for the artificial adjective, the classifier –aäbik in Ojibway is used for plastic, along with other hard surface materials like metal, glass and stone. However, Akatek has separate classifiers for stone and wood, which according to Hiramatsu et al. should belong the same superordinate class of material. Conversely, Navajo classifies together fluffy non-compact matter (bunch of hair, grass, cloud, fog) and loose mushy objects (ice-cream, mud, fallen-over drunken person). These could go into the third superordinate material category, however fabric/cloth often has its own classifier (e.g., Tariana maka- for ‘things made of cloth’).

Finally, Kemmerer discusses functional classifiers, however, functions that are reflected in classifiers are multifaceted (manual handling, food gathering and preparation, chewing/drinking and social interaction). We therefore believe that corresponding category-specific neural activations to functional classifier semantics would have to be investigated for each type of function separately.

Based on the correspondences exposed here, it seems that languages’ features do provide windows into universal human nature of cognition. However, when describing what occurs, scientists hope to say something about what does not occur. Thus, what did not match between the two data sets may also contain relevant information about the cognitive or neural organization of human knowledge. Furthermore, the categories of Plant Parts, Kinship, Books, Speech, Valuables (mostly coins), Fire/light and Decorations were remarkably absent from the impairment data set. The most salient

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1 Higher-order regions are association areas that link information from unimodal areas or other association areas, for example the parahippocampal gyrus in the limbic system that links emotion with many sensory inputs.
difference between the two data sets was that the “Human” category was highly represented in the classifier domain, but a semantic impairment for ‘human’ does not seem to have been ever documented. The glaring absence of such a deficit is perhaps due to the pervasiveness of such a domain for our brains, due to the relevance of conspecifics to practically all cognitive functions, so that its representation is robust to damage. Nevertheless, some studies have discussed potential cases of conspecifics impairment (cf. Mahon and Caramazza, 2009, 2011). In the absence of prosopagnosia and a general naming deficit, one of these patients (patient APA; Miceli et al., 2000) was uniquely impaired for naming proper names of celebrities (Italian or foreign politicians, actors, TV personalities or journalists), and she did not display similar problems with common names, animals or geographical names. In addition, she was impaired on information (e.g., profession, appearance, geographical origin) of these famous people, compared to controls. Another patient (patient KS; Ellis et al., 1989) suffered a memory loss for people after a right temporal lobe resection due to epilepsy; she was not clinically amnesic, but her deficit extended to famous animals (Moby Dick, Lassie), buildings (the Kremlin, the White House) and product names (Typhoo [tea], Raleigh [bicycle]), which rather hint at a specificity deficit. Interestingly, Gentileschi et al. (2001) proposes that the loss of exemplar semantics is an independent loss in the long-term semantic memory archives, and that ‘identity-specific semantics’ should be conceived as a special semantic subsystem. The ‘unique entities’ hypothesis was specifically put to test with patient CD described by Gainotti et al., (2008), who suffered a cross-modal famous persons recognition deficit, unable to recognize people from their face, voice or name. The unique entity hypothesis was confirmed since besides being impaired in recognizing famous people (4% correct from photos, 0% correct from verbal definition), she was clearly impaired on familiar towns (5–10% correct) and famous monuments (12–21% correct). Monuments were included for their shape-like similarities to persons, much unlike the diffuse shape of cities.

On one interpretation, conspecific knowledge of other humans could be considered ‘expert knowledge’ and therefore more specific and detailed knowledge. An interesting case that could support this idea is one patient (Barbarotto et al., 1995) who suffered from a general deficit for ‘biological categories’, but who was also impaired in recognizing faces, whereas the only non-biological category severely impaired was architecture (incidentally, the patient’s former academic specialty, Capitani et al., 2003). Typically, tests of famous persons involve naming a public person, e.g., a musician or a politician by looking at a photo of their face, although face recognition need not be a decisive feature for possessing knowledge about people. Nine further studies claim a famous person deficit (patients MF, Felicia, SRB, JMC, BD, Emma, MC72, MA and MI; see Supplementary materials, supplement 1 for references). Among all registered cases, three had in addition a deficit in recognizing individual family members or friends (SRB, BD, and Emma), and three showed a biographical information deficit (MF, SRB, Emma, MC72, APA). Visual recognition was the overall ability tested but in one case (BD) the deficit extended to familiar people’s voices and names (Forde et al., 1997). Three of these patients had in addition a deficit in naming or recognizing famous buildings and monuments (MF, JMC, Emma and KS). In our data set, twelve patients suffered from prosopagnosia (had perceptual problems in recognizing faces). However, only two patients, SRB and Emma, were impaired for famous persons while also suffering from prosopagnosia.

Beyond the above cases it remains unclear if proper naming deficits are due to specific information about unique entities (Harris and Kay, 1995), or if they indeed refer to humans as a semantic category. The representation of a ‘human’ category thus appears robust to damage, not only when localized but also diffuse (e.g., some dementia patients may lose altogether the ability to identify from names and pictures both animate and inanimate objects, as well as showing difficulties with names and pictures of famous people, but not people per se; cf. Snowden et al., 2012; Gainotti, 2015a).

Perceptual face impairments clearly differ from a putative ‘human’ impairment since a corresponding impairment should reveal itself at the basic-level of recognition, as is the case for classifiers (Kemmerer, 2017). For an impairment to count as a ‘Human impairment’, the criteria must be fulfilled that the patient fails to understand that something is or is not a human. By contrast, humans are preferentially encoded at the individual level (Shelton et al., 1998; Gauthier et al., 2000). In fact, prosopagnosics rather fail to identify a specimen of the human category. Moreover, awareness of the individual can even be preserved since quite often these patients turn to alternative sensory cues like a person’s voice, gait, hands or hairstyle for identification (Biotti et al., 2017).

Furthermore, in a failure to identify someone as a human being, we would see a deficit that affects the whole human body. Prosopagnosia affects a body part with some uniqueness markers to it. There is some evidence that face impaired persons can also be impaired for body knowledge (e.g., Biotti et al., 2017); however, body perception deficits do not appear to be a universal feature of prosopagnosia (see also Susilo et al., 2013). To the contrary, Moscovitch et al., (1997) report that neuropsychological patients exhibiting severely impaired body perception can show spared face perception, thus dissociating the cognitive processing of bodies and faces. In fact, normal body perception is broadly typical among developmental prosopagnosics, and many of these patients report using typical bodily features like body motion and shape to replace their missing face recognition abilities. This is in line with the fact that the body and face neural networks are adjacent but parallel (Peelen and Downing, 2007), as well as a TMS study by Pitcher et al. (2009), targeting the extrastriate body area (EBA) and the occipital face area (OFA), with temporary impairment effects for body and face knowledge, respectively.
Finally, for recognizing a category-specific deficit as a match to the Human category in classifiers, the impairment should not extend beyond humans, especially not in a semantically unmotivated way. However, prosopagnosic symptoms can be associated to inanimata, e.g., cars and guns (Duchaine et al., 2007) or similar geometrical shapes (Laeng and Caviness, 2001). Ultimately, the ‘expertise hypothesis’ proposes that faces are analyzed by the same mechanisms necessary for the identification of classes of ‘expertise’ (Diamond and Carey, 1986; McGugin et al., 2012), such as birds or cars (Gauthier et al., 2000).

Among these types of human-related knowledge impairments, one could consider also some cases of the neurological disorders called Capgras or Cotard syndromes (Young et al., 1992; Young, 2008) where patients may believe that a family member has been replaced by another human or that their human body is dead, inexistent or missing internal organs. Notably, these cases also operate at the individual or subordinate category level. All in all, we prefer in the present context to remain conservative and consider such impairments as not fully compatible with a more comprehensive ‘human’ semantic category.

Another remarkable contrast in the two data sets is the high representation of the already mentioned ‘shape’ classifiers, which find no correspondence in semantic impairments, e.g., an impairment for the knowledge of ‘all things that have round shapes’ (although such an impairment may exist as a perceptual impairment; Kosslyn et al., 1995; Laeng and Caviness, 2001). One study (Arguin et al., 1996) investigated shape impairment. In a series of experiments using synthetic (silhouette or line drawing) stimuli defined along the dimensions of elongation, curvature (bending, round) and tapering, patient ELM was diagnosed with a ‘shape integration impairment’. However, the deficit was modified by semantic category: while ELM was severely impaired in the visual recognition of fruits and vegetables most artifact items were entirely spared despite when presented with identical, abstract shapes. For example, a stylized elongated shape silhouette was presented alternatively as an asparagus or a pen. In similar pairs of cucumber/cigar, melon/balloon, orange/baseball, all pairs presented with the same shapes, ELM took significantly longer to identify the items and was significantly more error-prone if they were conceived of as fruits or vegetables than if they represented man-made objects (Arguin et al., 1996: 261). In other words, his agnosia related selectively to a biological category and was not a general shape deficit. A potential explanation could be that shapes reflect properties or elementary features of objects that are ubiquitous across kinds but never constitute uniquely identifying features of a specific category (e.g., fruits are typically round but so are many things). An alternative is to understand shapes in classifiers as feature extraction and in impairment as feature integration. In another study (Lecours et al., 1999) Patient IL exhibited a visual object recognition disorder that the authors explain in terms of an impaired access to structural knowledge. On a visual picture-to-auditory word-matching test the stimuli varied along differences in one, two or three shape dimensions of elongation, curvature and tapering on unmatched word-picture trials. IL’s performance was an inverse function of the number of dimensions by which the picture differed from the target object. However, there was an interaction between semantic category (fruit/vegetables vs. artifacts) and degree of shape difference that was absent in controls. The disorder was therefore conceived of as shape integration impairment modified by semantic proximity. It would, however, have to be further investigated if this is a viable explanation.

It may be surprising that size has not shown up as a domain that dissociates into small and large objects in impairments. Size has been a topic in cognitive neuroscience and has been successfully investigated with neuroimaging methods (e.g., Konkle and Oliva, 2012; Konkle and Caramazza, 2013). Small manipulable objects were impaired with patient YOT, compared to large man-made objects (Warrington and McCarthy, 1987), however, to our knowledge, the opposite deficit has not been found, that large man-made objects are impaired. There are classifiers for small things and for big things in classifier languages, although the big thing category may not correspond to what was tested in Warrington and McCarthy: for example, in Mandarin Chinese the ‘big’ classifier classifies outdoor objects that stand out in terms of size to surrounding elements, such as tall and large buildings like skyscrapers and towers and man-made constructions like bridges and pagodas, but also naturally occurring land-marks like mountains and icebergs, large rooms with depth (cinemas, auditoriums) and with marked outer boundaries (islands, fortresses, water reservoirs), which shows that it is really a classifier for navigation within scenes. The ‘large, outdoor man-made objects’ that YOT was tested for included buildings but also land, air and water vehicles, that is, objects that typically have their own classifiers. In conclusion, we think this is an interesting semantic domain that deserves to be further investigated in the two fields.

We stated in the introduction that the categories of category-specific impairments are remarkably aligned with the categories that fall out of the functional imaging literature. Interestingly, a widespread method in cognitive neuroscience for studying normal brain function is neuroimaging (e.g., fMRI), which indicates that the healthy human brain possesses an organization or specialization for cognitive domains reflected in patterns of anatomically localized activations (Kemmerer, 2017). For example, neuroimaging studies have identified a perceptual network for detecting biological motion (e.g., Giese and Poggio, 2003; Grossman et al., 2006), which may be instrumental for representing animacy and our detection of conspecifics as well as non-conspecifics (Buccino et al., 2004). The knowledge of food would be represented in sensory areas of the brain, especially those that serve gustatory, olfactory (Rolls, 2015) and visual functions (Pohl et al., 2017). Surprisingly, less investigation has gone into the neural representation of plants, fruits and
vegetables but, in general, there is a wealth of research on the brain’s structure for representing an object’s shape or size (e.g., Kourtzi and Kanwisher, 2000; Konkle and Olivia, 2012; Baldassi et al., 2013; Konkle and Caramazza, 2013; Jozwik et al., 2016). Studies on the control of the human hand in relation to object’s size and shape (e.g., Castiello, 2005) may shed light onto aspects of classifier systems that do in fact distinguish between pinch grip sized and whole hand grasp sized actions toward external objects (Conklin, 1981: 246). As for musical instruments, their acoustic and emotional associations (e.g., Juslin and Västfjäll, 2008; McAdams et al., 2017) could perhaps explain their impairment along with living things. Some suggest the presence of neural networks for representing ‘other minds’ and understanding others’ actions (e.g., Rizzolatti and Craighero, 2004; Downing et al., 2006; Carrington and Bailey, 2009; Caspers et al., 2010).

To conclude, the impairment debate within neuropsychology has invoked processes meant to be valid for all brains or regardless of their culture or language. A similar ubiquity is characteristic of classifier languages and nominal systems have the potential to give us clues to how humans conceptually organize their world. Indeed, linguistic data on classifiers may assist the search and lead to the discovery of “new” types of impairments within the neurological population. The linguistic evidence could also provide converging evidence for theories on semantic impairments. In turn, cognitive neuroscience could also mediate current debates within linguistics in the quest of language universals. Considering the fact that classifiers possess more variants than impairments that so far have been discovered, a plausible account for the asymmetry may lie in the extraordinary functional flexibility of language. Semantic categories could wax or wane at a much faster rate in linguistic than within brain mechanisms or cognitive structures. The apparent absences of some of the categories in the patient data are particularly in need of a deeper examination. Hopefully, our claim of a correlation between semantic deficits and classifiers will spur fruitful debates at the nexus of several related fields within the cognitive sciences, neuroscience and in linguistics. Our motivation is to inspire scientists in the two fields to continue to look for more differences or commonalities. A potentially more mature universal theory of the mind’s semantic system should emanate from the empirical findings in their aftermath.

Author contributions

ML and BL conceived the idea for the present survey. ML, AB and ST collected the classifier data and ML supervised this data collection. ST and ML collected the impairment data and ML and BL supervised the overall process. BL and AB carried out the statistical analyses and ML, BL and AB created the Figures. ST assisted on editing tasks. ML wrote the initial manuscript with contributions from all co-authors. BL and ML revised the final work and BL supervised this process.

Conflict of interest

The authors declared no conflict of interest with respect to the authorship or the publication of this article.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:10.1016/j.lingua.2020.102929.

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