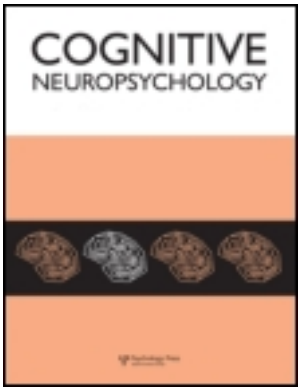

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The organization of the conceptual system: The case of the "object versus action" dimension

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The organization of the conceptual system: The case of the "object versus action" dimension

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There are very numerous reports in the neuropsychological literature of patients showing, in naming and/or comprehension tasks, a disproportionate deficit for nouns in comparison with verbs or a disproportionate deficit for verbs in comparison with nouns. A number of authors advanced that, in at least some or even in every of these reported cases, the noun/verb dissociation in fact reflected an underlying conceptual deficit disproportionately affecting either object or action concepts. These patterns thus would put an additional constraint on theories of conceptual knowledge organization, which should be able to explain how brain damage could selectively disrupt the concepts of objects or the concepts of actions. We have reviewed 69 papers (published from 1984 to 2009) that reported a pattern of a noun or a verb disproportionate deficit in a single-case, multiple-case, or group study of brain-damaged patients with various aetiologies. From this review, we concluded that none of these studies provided compelling evidence in favour of the interpretation that the observed noun or verb disproportionate deficit arose at the conceptual processing level and, accordingly, that this level may be organized according to the "object/action" dimension. Furthermore, we argue that investigating conceptual impairments in brain-damaged patients according to the "object/action" dichotomy is not empirically fruitful if the purpose is to inform theories of conceptual knowledge organization. In order to provide evidence relevant to these theories, one needs to consider finer grained distinctions within both the object and the action category when investigating the scope of the patients' conceptual impairment.

Keywords: Organization of conceptual knowledge; Object concepts; Action concepts.

The various patterns of category-specific conceptual deficits presented by brain-damaged patients can provide strong constraints on theories of how conceptual knowledge is represented and organized in the human mind and brain. During the last three decades, detailed examinations of patients having a selective or disproportionate conceptual impairment for one category of concrete, physical objects compared to other categories of objects revealed important dimensions along

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which conceptual knowledge of objects is organized at the functional and neural level (for a review, see Capitani, Laiacona, Mahon, & Caramazza, 2003). Thus, patients were reported who were disproportionately impaired for the concepts of living things (i.e., animals and plants) compared to the concepts of nonliving things (i.e., man-made objects or artifacts; e.g., Laiacona, Barbarotto, & Capitani, 1993; Samson, Pillon, & De Wilde, 1998; Sartori & Job, 1988; Warrington & Shallice, 1984) or disproportionately impaired for the concepts of nonliving things compared to the concepts of living things (e.g., Lambon Ralph, Howard, Nightingale, & Ellis, 1998; Sacchett & Humphreys, 1992; Warrington & McCarthy, 1983). Patients were also reported who were disproportionately impaired for the concepts of living animate things (i.e., animals) compared to living inanimate things (i.e., plants; Caramazza & Shelton, 1998) or the reverse (e.g., Hart, Berndt, & Caramazza, 1985; Samson & Pillon, 2003). In addition, when appropriately assessed, these patients did not show disproportionate impairment for a specific type of semantic knowledge like visual or functional knowledge (Capitani et al., 2003). Such patterns firmly established the fact that the living versus nonliving and, within the living, the animate versus inanimate dimensions, were organizing dimensions of object conceptual knowledge in mind and brain and that it was these dimensions—not or not only dimensions that might be correlated with them like the differential weighting of various types of semantic knowledge across the categories of concepts—that ought to be accounted for by any theory of conceptual knowledge organization (Caramazza & Mahon, 2003; Martin, 2007; Samson & Pillon, 2003).

Another, more fundamental, distinction has been claimed to be relevant for the issue of the organization of conceptual knowledge: that between the concepts of concrete objects (or entities) and the concepts of concrete actions (or events; e.g., Bird, Howard, & Franklin, 2000; Damasio & Tranel, 1993; Gainotti, 2004, 2006; Kable, Lease-Spellmeyer, & Chatterjee, 2002; McCarthy & Warrington, 1985; Vigliocco, Vinson, Lewis, & Garrett, 2004). The main evidence advanced in support of this claim comes from the numerous reports of patients showing, in naming and/or comprehension tasks, a disproportionate deficit for nouns in comparison with verbs or a disproportionate deficit for verbs in comparison with nouns (for reviews, see Druks, 2002; Mätzig, Druks, Masterson, & Vigliocco, 2009; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011). Most of these reports referred to these patterns as "noun/verb" dissociations—that is, dissociations between two grammatical, not semantic, categories of words. However, in almost all these reports, the naming and comprehension tasks included concrete nouns and concrete verbs, which correspond to physical objects and actions, respectively. Thus, a number of authors advanced that "for at least some" of these reported cases (Gainotti, 2004, 2006; Kable, Kan, Wilson, Thompson-Schill, & Chatterjee, 2005; Kable et al., 2002; Laiacona & Caramazza, 2004; Silveri, Perri, & Cappa, 2003; Vigliocco et al., 2004) or in every case (Bird, Howard, et al., 2000), the noun/verb dissociation in fact reflected an underlying conceptual deficit selectively or disproportionately affecting either object or action concepts. These patterns thus would put an additional constraint on theories of conceptual knowledge organization, which should be able to explain how brain damage could selectively disrupt the concepts of objects or the concepts of actions.

Here we argue, first, that the neuropsychological evidence usually cited in support of the view that the conceptual system may break down along the "object/action" dimension is far from compelling and, second, that this dimension is not empirically relevant for studying the patterns of conceptual impairments.

Do grammatical category-specific deficits arise at the conceptual level?

We have reviewed 69 papers published from 1984 to 2009 (see references and main results in Appendix) that reported a grammatical category-specific deficit in a single-case, multiple-case, or

group study of brain-damaged patients with various aetiologies. By the phrase "grammatical category-specific deficit"—and also by "noun/verb disproportionate deficit/impairment" that we use interchangeably with it—we mean any pattern of performance showing a significant difference between noun and verb processing. Such a pattern may correspond to a selective deficit for one grammatical category of words, nouns, or verbs—in this case, the patient's (or group of patients') performance is impaired only for one category—or to a disproportionate deficit for nouns compared to verbs or for verbs compared to nouns—in this case, the patient's (or group of patients') performance is impaired for both categories but is more impaired for one category than the other. However, we could not consider this distinction here because, the most often, the patient's (or group of patients') performance with nouns and verbs was not compared to the performance of control subjects in order to test for the presence of a selective or a disproportionate deficit (see, for example, Crawford & Garthwaite, 2005).

From this review, we concluded that none of these studies has documented with an appropriate methodology the existence of a disproportionate impairment for the concepts of objects compared to the concepts of actions or the reverse. In other words, none of these studies provided compelling evidence in favour of the interpretation that the observed noun or verb disproportionate deficit arose at the conceptual processing level and, accordingly, that this level may be organized according to the "object/action" dimension.

Our evaluation of the extant evidence is based on the assumption, with which most researchers in the field of semantic disorders would certainly agree, that a deficit impairing the concepts of objects more than the concepts of actions, or the reverse, should cause the same pattern of noun or verb disproportionate deficit in word production and comprehension, and in both the spoken and the written modalities. A further assumption, which may be less shared, is that the same pattern of noun/object or verb/action disproportionate deficit should be found whether comprehension is probed from verbal (words) or visual (pictures) stimuli.

These assumptions follow from a conception of the conceptual system as a central and unitary system representing the concepts that give meaning to both verbal (spoken and written) and nonverbal (i.e., visual or auditory) stimuli and percepts and onto which and from which both verbal (spoken and written) and nonverbal information is mapped. This conception is widely held in the tradition of neuropsychological research (e.g., Caramazza & Hillis, 1990; Funnell, 1995; Humphreys & Riddoch, 1988; Laiacona et al., 1993; Lambon Ralph, McClelland, Patterson, Galton, & Hodges, 2001; Tyler, Moss, Durrant-Peatfield & Levy, 2000), but it is not universal. Some theorists assume two distinct levels of mental representations, one representing word meanings (and associated with word forms) and the other representing conceptual representations per se (e.g., Bierwisch & Schreuder, 1992; Tranel, Kemmerer, Adolphs, Damasio, & Damasio, 2003; Vigliocco et al., 2004), or distinct modality-specific meaning systems, each associated with an input modality, like a verbal and a visual semantic system (Beauvois, 1982; Paivio, 1978; Shallice, 1988; Warrington, 1975; Warrington & McCarthy, 1994). However, there are both theoretical (e.g., Jackendoff, 1983; Lakoff, 1987) and empirical (e.g., Chertkow, Bub, & Caplan, 1992; Hillis & Caramazza, 1995a; Hillis, Rapp, Romani, & Caramazza, 1990; Riddoch, Humphreys, Coltheart, & Funnell, 1988) justifications for preferring the more parsimonious, unitary view over the multiple-level or multiple-system view of the mental representation of meaning.

We found that, in the great majority of the reviewed studies, either there was evidence that the patient(s) did not present a consistent pattern of noun or verb disproportionate deficit across processing modalities, or evidence from different modalities was lacking. In a minority of studies, the patient(s) did present a consistent pattern of noun or verb disproportionate deficit across modalities, but the available data were still not sufficient to provide evidence that the grammatical category-specific deficit had a conceptual origin.

Patterns of grammatical category-specific deficits inconsistent across processing modalities

In several studies (see Appendix, Table A1(a)), the patients presented a noun or a verb disproportionate deficit in a picture naming task, but, in a comprehension task (the most often, a word-picture matching task), the patients were either not impaired at all or as impaired for both categories of words (Bates, Chen, Tzeng, Li, & Opie, 1991; Berndt, Mitchum, Haendiges, & Sandson, 1997; Bird, Howard, et al., 2000; Breedin, Saffran, & Schwartz, 1998; Cotelli et al., 2006; De Renzi & di Pellegrino, 1995; Hernandez, Costa, Sebastian-Galles, Juncadella, & Rene, 2007; Hillis et al., 2006; Jonkers & Bastiaanse, 1998; Kambanaros, 2008; Kim & Thompson, 2000, 2004; Laiacona & Caramazza, 2004; Marshall, Chiat, Robson, & Pring, 1996; Marshall, Pring, Chiat, & Robson, 1996; Miceli, Silveri, Nocentini, & Caramazza, 1988; Miozzo, Soardi, & Cappa, 1994; Shapiro & Caramazza, 2003a, 2003b; Silveri & Di Betta, 1997; Silveri, Perri, et al., 2003; Silveri, Salvigni, Cappa, Della Vedova, & Puopolo, 2003; Sörös, Cornelissen, Laine, & Salmelin, 2003; Yip, Law, Hsuan-Chih, & Li, 2006; Zingeser & Berndt, 1988). There is also a group study (Appendix, Table A1(b)) of patients with semantic dementia who showed a noun disproportionate deficit in a word–picture matching task but whose performance in a picture naming task revealed no significant difference between nouns and verbs (Cotelli et al., 2006).

In another set of studies (Appendix, Table A1(c)), the patients presented with a grammatical category-specific deficit in both production and comprehension, but the most impaired category was different in production and comprehension. Thus, H.Y. (Berndt et al., 1997), E.B.A. (Hillis & Caramazza, 1995b), J.R. (Shapiro, Shelton, & Caramazza, 2000), and T.P. (Yoon, Humphreys, & Riddoch, 2005) were more impaired in naming nouns than verbs but, in comprehension, they were more impaired with verbs than with nouns. In other cases (Appendix, Table A1(d)), the dissociation observed in comprehension was specific to the type of stimuli (words vs. pictures vs. words and pictures) used to probe the comprehension of objects and actions (Bak & Hodges, 2003; Bak et al., 2006; d'Honincthun & Pillon, 2008). For example, in Bak and Hodges's (2003) study, a group of patients with semantic dementia showed a disproportionate impairment with nouns compared to verbs in a semantic association task (Pyramids and Palm Trees Test, Howard & Patterson, 1992; Kissing and Dancing Test, Bak & Hodges, 2003) when the items were presented as written words but did not show any noun/verb dissociation when the same items were probed with pictures of objects and actions. Conversely, their group of patients with the frontal variant of frontotemporal dementia did not show any dissociation between nouns and verbs in the semantic association task when probed with written words but the same items probed with pictures yielded a disproportionate impairment with the pictures of actions compared to the pictures of objects. In the study by Bak and colleagues (2006), which reported the pattern of performance with nouns and verbs in two individuals (a father and his son) with progressive supranuclear palsy associated with dementia, the pattern of verb disproportionate deficit of both individuals was not consistent across the two comprehension tasks used, namely, a word–picture matching task and an association task comprising exclusively picture stimuli (Pyramids and Palm Trees Test and Kissing and Dancing Test). Individual I was significantly more impaired with verbs than nouns in the word–picture matching task, but his performance in the association task was not significantly different for objects and actions. Across four assessments during a six-year period, Individual II consistently showed no significant difference between nouns and verbs (and, in fact, ceiling performance for both nouns and verbs) in the word–picture matching task but showed a comprehension impairment in the association task with poorer performance for actions than for objects in the first two (but not the last two) testing sessions.

Finally, several studies (Appendix, Table A1(e)) reported cases presenting with a distinct

noun/verb pattern in the spoken versus written modality of verbal production (Caramazza & Hillis, 1991; Collina, Marangolo, & Tabossi, 2001; Hillis et al., 2006; Hillis, Oh, & Ken, 2004; Hillis, Tuffiash, & Caramazza, 2002; Hillis, Wityk, Barker, & Caramazza, 2003; Marshall, Pring, & Chiat, 1998; Rapp & Caramazza, 1998, 2002). For example, patients H.W. (Caramazza & Hillis, 1991), E.T. (Collina et al., 2001), and A.T.N. and M.M.L. (Hillis et al., 2002) were disproportionately impaired in naming verbs compared to nouns in oral naming while their written naming was spared for both verbs and nouns. On the other hand, patients S.J.D. (Caramazza & Hillis, 1991), Cases 1 and 2 reported by Hillis et al. (2003), and P.W. (Rapp & Caramazza, 1998) were disproportionately impaired in naming verbs compared to nouns in written naming while their oral naming was relatively spared for both verbs and nouns.

These contrastive patterns of grammatical category-specific deficit across processing modalities suggest that nonsemantic processing levels—namely, the levels of spoken and written word recognition, the levels of spoken and written word production, and the visual level of picture processing—are sensitive to the noun/verb or the object/action distinction and may thus be the locus of a modality-specific disproportionate deficit for nouns (or object pictures) or verbs (or action pictures). In the lexical domain, the hypothesis has been advanced that distinct functional and neural processes are engaged in noun and verb processing at the levels of the phonological and orthographical form retrieval and recognition because of their having distinct syntactic roles in sentence processing (Berndt & Haendiges, 2000; Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1988) or distinct morphological properties in word formation (Shapiro & Caramazza, 2003a; Shapiro et al., 2000).[1] As for the visual domain, there is neuropsychological evidence supporting the view that separate processes mediate visual recognition of objects and actions (e.g., Cubelli, Marchetti, Boscolo, & Della Salla, 2000; Ferreira, Ceccaldi, Giusiano, & Poncet, 1998; Rothi, Ochipa, & Heilman, 1991). Among other differences, object recognition relies on shape/form processing (Biederman, 1987; Marr, 1982; Riddoch & Humphreys, 1987), whereas action recognition requires visual motion processing, whether the actions are displayed as dynamic or static stimuli (e.g., den Ouden, Fix, Parrish, & Thompson, 2009). Evidence from neuroimaging studies also supports the existence of distinct visual processing streams for object form and motion, in the ventral occipitotemporal cortex and the lateral temporal cortex, respectively (e.g., Beauchamp, Lee, Haxby, & Martin, 2002, 2003; Chao, Haxby, & Martin, 1999; Ishai, Ungerleider, Martin, & Haxby, 2000; Martin, 2007).[2]

[1] Another interpretation has been suggested for these patterns of grammatical category-specific deficits that were found in only one, spoken or written, word processing modality. This interpretation assumed that the conceptual representations of actions and objects are subserved by spatially segregated systems. Damage to the pathway from one of these systems to one modality-specific lexical system would result in a modality-specific deficit for either actions—that is, typically, verbs—or objects—that is, typically, nouns (e.g., Damasio & Tranel, 1993; Rapp & Caramazza, 1998). Although this account cannot be rejected, it needs independent evidence supporting its initial assumption—namely, that the concepts of actions and objects are subserved by segregated systems—just the evidence we are arguing here is lacking.

[2] Admittedly, any pattern of noun/verb dissociation that is inconsistent across tasks or processing modalities does not necessarily result or does not result only from a deficit located at a nonsemantic (lexical or visual) level of processing. To begin with, inconsistencies could result from an insufficient control of the extraneous variables affecting the performance in each task or processing modality. Furthermore, inconsistencies could be due to some modality- or task-specific processing demands that interact with grammatical category. For instance, it could be argued that performance in a comprehension task is facilitated when probed from pictures compared to words but only for objects (nouns), not for actions (verbs), because, say, in the case of objects but not of actions, the visual-to-conceptual mapping is less arbitrary than the word-to-conceptual mapping (i.e., in the picture modality, the visual properties of an object, but not of an action, could directly activate some of its conceptual properties). However, maintaining a semantic account for the noun/verb dissociation in such cases would require a developed analysis of the task demands and a motivated hypothesis about why these would differ according to grammatical category—an approach that was not attempted in the studies reported.

Grammatical category-specific deficits reported in production or comprehension only without data in the other modality

Given the evidence that a grammatical category-specific deficit could arise at a nonconceptual level of processing and, in particular, at the level of word retrieval processes for production, the numerous cases of patients (Appendix, Table A2(a)) for whom only naming performance was reported cannot provide relevant evidence for the issue of the representation of object and action concepts (Arévalo, Perani, Cappa, Butler, Bates, & Dronkers, 2007; Bastiaanse & Jonkers, 1998; Berndt & Haendiges, 2000; Berndt, Haendiges, Burton, & Mitchum, 2002; Bi, Han, Shu, & Caramazza, 2007; Bird, Howard, et al., 2000; Breedin & Martin, 1996; Cappa, Binetti, Pezzini, Padovani, Rozzini, & Trabucchi, 1998; Collina et al., 2001; Cotelli et al., 2007; Crepaldi et al., 2006; Damasio & Tranel, 1993; De Bleser & Kauschke, 2003; Hillis et al., 2004; Lu et al., 2002; Luzzatti et al., 2002; Mätzig et al., 2009; Menichelli & Semenza, 2006; Miceli et al., 1984; K. M. Robinson, Grossman, White-Devine, & D'Esposito, 1996; Silveri & Ciccarelli, 2007a, 2007b; Williamson, Adair, Raymer, & Heilman, 1998; Zingeser & Berndt, 1990).

In relation to this point, it is worth noting that the most often cited paper reporting on a double dissociation between nouns and verbs supposedly showing evidence for the existence of a neural separation between the concepts of objects and actions, was a paper by Damasio and Tranel (1993), who reported the patients' performance with nouns and verbs in a picture naming task only. Furthermore, the authors reported that the three patients—Boswell and AN-1033 who were disproportionately impaired in naming nouns and KJ-1360 who was disproportionately impaired in naming verbs—could retrieve the concepts of the objects or actions they could not name.[3] As a matter of fact, contrary to how this study has consistently been reported in the literature, the authors viewed the impairment of the three patients as a deficit in *word-form retrieval* affecting nouns more than verbs, not as a conceptual deficit affecting objects more than actions (but see Footnote 1).

There are also two group studies (Appendix, Table A2(b)) reporting a verb disproportionate deficit that provided data in comprehension only (Grossman et al., 2008; Rhee, Antiquena, & Grossman, 2001). Such evidence presents the same kind of ambiguity as that obtained from naming only. In particular, in both these studies, the comprehension tasks probed written words, and there is evidence that the level of written-word recognition is sensitive to the noun/verb distinction (e.g., case H.Y., Berndt et al., 1997; and case E.B.A., Hillis & Caramazza, 1995a). Neither of these two studies provided data that could rule out that the verb deficit arose at this modality-specific lexical processing level (e.g., reporting the patients' performance in a lexical decision task with written stimuli).

Patterns of grammatical category-specific deficits that are consistent across processing modalities

Still, there are some single-case reports of patients presenting with a noun (Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Miceli et al., 1988; Parris & Weekes, 2001; G. Robinson, Rossor, & Cipolotti, 1999; Silveri, Perri, et al., 2003) or a verb (Daniele et al., 1994; Hernandez et al., 2008; McCarthy & Warrington, 1985; Miceli et al., 1988) disproportionate deficit, as well as group studies reporting a verb disproportionate deficit (Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Cotelli et al., 2006; Kim & Thompson, 2004; White-Devine et al., 1996) that was found in both production and comprehension (Appendix, Table A3). The association of a noun or a verb deficit in both production and comprehension is consistent with the hypothesis that the grammati-

[3] Except that Boswell could not retrieve the concepts of animals (but only these concepts within the noun set; the concepts of vegetables and tools/utensils were not impaired).

cal category-specific deficit had a conceptual origin in these cases.

However, the results of these studies were not without ambiguities. First, in some cases, the pattern of noun/verb difference was not significant in all processing modalities (Case G.P., Daniele et al., 1994) or not consistent across the various item sets used to probe noun and verb processing (Case C.G., Silveri, Perri, et al., 2003) or not consistent across the attempted replications of the same task with the same items (Case A.A., Miceli et al., 1988). In a patient presenting with a primary progressive aphasia and a verb deficit (J.P.G., Hernandez et al., 2008), the progressive deterioration of verb naming over time was not associated with a parallel deterioration of verb comprehension.

One possible reason for the discrepant results across the different sets of items could be the lack of control of variables like concept familiarity or imageability, which are known to influence the performance of brain-damaged subjects and may differ between nouns and verbs. Thus, verbs tend to be lower in imageability than nouns, and it has been shown in several cases that a seemingly disproportionate verb deficit disappeared when imageability of nouns and verbs was controlled for (Bird, Howard, et al., 2000; Bird, Lambon Ralph, Patterson, & Hodges, 2000; Conroy, Sage, & Lambon Ralph, 2006; Luzzatti et al., 2002). On the other hand, name frequency (Szekely et al., 2005) and concept familiarity (Mätzig et al., 2009) tend to be higher for verbs than nouns. Actually, this drawback was present in all the studies reported in this section. Although the noun and verb sets were matched according to name frequency in all but one study (i.e., McCarthy & Warrington, 1985), concept familiarity was matched in only two of them (i.e., Hernandez et al., 2008; Parris & Weekes, 2001) and concept imageability in only one (i.e., Hernandez et al., 2008).

Second, with the exception of the study by Silveri, Perri, et al. (2003), these studies did not assess noun and verb processing in both the spoken and written modalities of naming and word comprehension, so that potential differences between both verbal modalities might have been undetected.

Third, and more importantly, two plausible alternative explanations for the association of a disproportionate noun or verb deficit in production and comprehension were not addressed in these studies: (a) The association could be due to two (disproportionate) noun or verb deficits, one affecting the mechanisms for accessing the spoken or the written form of nouns or verbs in production, the other affecting the mechanisms for recognizing the spoken or the written form of nouns or verbs in comprehension; (b) The association of a disproportionate deficit with nouns compared to verbs or vice versa in both tasks could be due to disproportionate difficulties with the visual, not the semantic, processing of the pictures of objects compared to the pictures of actions or vice versa, which are included in both tasks. These are plausible alternative hypotheses since, as we have shown above, grammatical category-specific deficits are likely to arise at a lexical or visual recognition processing level. Yet none of these studies reported data that would allow us both to rule out a category-specific lexical recognition deficit as the source of the noun or verb comprehension deficit (e.g., data from an auditory or visual lexical decision task with nouns and verbs) and a deficit in visuostructural or visual motion/gesture processing as the source of the difficulties with object or action pictures, respectively (e.g., data from a real/unreal object decision task or a gesture recognition task).

Also, in the cases showing disproportionate difficulties with verbs (or action pictures) compared to nouns (or object pictures), there is the concern that recognizing actions from static depictions (photographs or drawings) is probably more resource demanding than recognizing objects from the same kind of depictions (see, for evidence, den Ouden et al., 2009). With static action pictures, not only are the stimuli and the task less familiar in everyday life than with object pictures, but it also requires recovering information that is lacking in static scenes (i.e., the temporal and movement features of the action) and yet crucial for the recognition of the

action. Therefore, brain-damaged patients who suffer sometimes executive resource limitations may have more difficulty in processing still action pictures than object pictures. One striking feature of the great majority of the patients with a verb disproportionate deficit in both naming and comprehension was that they presented a degenerative brain disease (see Appendix, Table A3), a condition that is typically associated with executive resource limitation (Hodges et al., 1999; Miller et al., 1991; Silveri, Salvigni, et al., 2003). Incidentally, the most often cited evidence of a verb disproportionate deficit supposedly arising at a conceptual level is the case study of patient R.O.X. (McCarthy & Warrington, 1985) who suffered a progressive degenerative disease. In a previous study, we have shown that the verb disproportionate deficit that a patient with the frontal variant of frontotemporal dementia presented when her naming or comprehension was assessed from static depiction of actions (i.e., photographs) disappeared when naming or comprehension was assessed from videotaped actions or verbal stimuli (d'Honincthun & Pillon, 2008). Among the eight studies that have reported a verb disproportionate deficit in both production and comprehension (Bak et al., 2001; Cotelli et al., 2006; Daniele et al., 1994; Hernandez et al., 2008; Kim & Thompson, 2004; McCarthy & Warrington, 1985; Miceli et al., 1988; White-Devine et al., 1996), none has probed action naming and/or comprehension with dynamic in addition to static action stimuli; no one has shown either that the pattern of verb deficit was also present in a task not involving picture stimuli—that is, using verbal stimuli only.

Is the "object/action" dichotomy empirically relevant?

The second issue we address briefly here is whether investigating even well-established conceptual impairments presented by brain-damaged patients according to the "object/action" (or "noun/verb") dichotomy is empirically relevant. We believe the answer is no if the patients' pattern of conceptual impairment is studied with the aim of informing theories of the functional and neural organization of conceptual knowledge.

A first, obvious, reason why the "object/action" dichotomy is not empirically relevant is that, as we have previously mentioned, it is now an uncontroversial fact that brain damage may selectively or disproportionately disrupt the concepts of living objects (animals and/or plants) compared to the concepts of nonliving objects (artifacts). On the basis of such evidence, most extant theories of conceptual knowledge organization (e.g., Caramazza & Shelton, 1998; Humphreys & Forde, 2001; Martin, Ungerleider, & Haxby, 2000; Simmons & Barsalou, 2003; Warrington & McCarthy, 1987) assume that the conceptual representations of living and nonliving objects are at least partly segregated. In this context, the relevant empirical question is not whether the concepts of "objects" can dissociate from the concepts of actions but, instead, how the concepts of living objects (animals and/or plants) and the concepts of nonliving objects (artifacts) are respectively related to the concepts of actions at the functional and neural level. Furthermore, failing to investigate a patient's conceptual knowledge separately for the various categories of objects may lead to fallacious conclusions like, for example, concluding to the existence of an "object" disproportionate impairment when the patient's poor performance for "objects" in fact merely reflected a disproportionate impairment for living objects (we return to this point later).

The second reason is that extant theories of conceptual knowledge organization assume distinct principles of organization, from which distinct predictions could be drawn as regards the patterns of conceptual impairment that may show up when categories of living things, artifacts, and actions, or even finer grained categories within artifacts and actions, are considered. Therefore, in order to provide evidence relevant to these theories, empirical studies should consider and assess the patients' performance for finer grained categories within both the object and the action sets, separately and within the same design.

For instance, within the currently most influential view of conceptual knowledge organization, which we call here the feature-based organization (FBO) theory, the conceptual representations of one category of objects, namely, artifacts, and of actions would be sustained by a partly overlapping system. Concepts of artifacts and concepts of actions (or, at least, of some kinds of artifacts and actions; cf. infra) should therefore pattern together after brain damage, that is, they should be both spared or both impaired. Within this theoretical framework, conceptual knowledge is represented in a distributed way over various functional and neural systems each representing a distinct type of featural knowledge, say, sensory (visual, auditory, somatosensory, olfactory), functional, motor, or manipulation knowledge (e.g., Allport, 1985; Barsalou, Simmons, Barbey, & Wilson, 2003; Humphreys & Forde, 2001; Martin et al., 2000; Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984). It is further assumed that the various categories of concepts are differentially weighted for each type of feature and, hence, represented in partially distinct systems. Thus, depending on the specific formulation given to the theory, it is assumed that both the concepts of artifacts and the concepts of actions are heavily weighted for functional (Bird, Howard, et al., 2000), motor (e.g., Allport, 1985; Boronat et al., 2005; Humphreys & Forde, 2001), or manipulation features (e.g., Gerlach, Law, & Paulson, 2002; Kellenbach, Brett, & Patterson, 2003; Noppeney, Josephs, Kiebel, Friston, & Price, 2005; Saccuman et al., 2006) whereas the concepts of living things would be heavily weighted for visual or sensory features. On this basis, selective damage to functional, motor, or manipulation features should selectively or disproportionately impair both the concepts of artifacts and the concepts of actions compared to the concepts of living things, whereas selective damage to visual features should relatively *spare* both the concepts of artifacts and the concepts of actions in comparison to the concepts of living things. More specifically, in the case of damage to functional features, the concepts of both manipulable (i.e., tools) and nonmanipulable artifacts and of both manipulation and nonmanipulation actions should be selectively impaired compared to the concepts of living things, whereas, in the case of damage to manipulation features, only the concepts of manipulable artifacts and of manipulation actions should be selectively or disproportionately impaired compared to the concepts of living things as well as compared to the concepts of nonmanipulable artifacts and of nonmanipulation actions.[4] (One may suppose that in the case of damage to motor features, the concepts of manipulable artifacts and of both manipulation and nonmanipulation actions should be more impaired than the concepts of living things and of nonmanipulable artifacts.)

On the other hand, within an alternative approach of conceptual knowledge organization, based on feature statistical properties instead of feature type, focal damage to the conceptual system could selectively or disproportionately impair the conceptual representations of objects compared to those of actions or the reverse. This theoretical approach views the conceptual system as a unitary space of semantic features within which some internal structure or heterogeneity emerges as a result of a differential distribution of semantic feature properties, like distinctive and shared features or the amount of feature intercorrelations, across the various categories of concepts (e.g., Caramazza, Hillis, Rapp, & Romani, 1990; Devlin, Gonnerman, Andersen, & Seidenberg, 1998; Tyler & Moss, 2001; Vigliocco et al., 2004). Some proposals within this general framework (Caramazza et al., 1990; Vigliocco et al., 2004) assumed that, because

[4] Let us mention that, within the domain-specific knowledge theory (Caramazza & Shelton, 1998; Mahon & Caramazza, 2009) as well, the concepts of tools could dissociate from the concepts of other artifacts (i.e., furniture, vehicles, clothing) in the case of brain damage, although for another principled reason. Tools, like conspecifics, animals, and plants, would be a category of objects whose efficient recognition and use had fitness value in human evolution and, hence, would be processed by a dedicated domain-specific conceptual system. This theory is silent, however, on the status of action concepts within the conceptual system.

members of a given category share many properties in common, which are highly intercorrelated, the semantic features of members of a category tend to cluster together within the conceptual space. Cluster analyses based on speaker-generated semantic features have shown that members of animate livings, inanimate livings, and artifacts grouped into three main separate clusters, which then divided into more specific clusters corresponding to coherent categories like land animals and birds, fruit and flowers, tools, vehicles, and clothing (Garrard, Lambon Ralph, Hodges, & Patterson, 2001; Small, Hart, Nguyen, & Gordon, 1995; Vigliocco et al., 2004). When the semantic features of object and action concepts are considered within the same cluster analysis, the results showed that members of both domains remain segregated (Vigliocco et al., 2004). On this basis, a focal "lesion" to the conceptual space may impair the conceptual representations of all or only one of the categories of objects by sparing the conceptual representations of actions or the reverse—that is, impair the conceptual representations of actions by sparing those of all or only one category of objects. In other proposals made within this general framework (Devlin et al., 1998; Tyler & Moss, 2001), it is assumed that correlated semantic features (i.e., features that often co-occur) support each other with mutual activation, so that strongly correlated features should be more resilient to damage within the conceptual system than those that are more weakly correlated. An analysis of speaker-generated features (Vinson, Vigliocco, Cappa, & Siri, 2003) indicated that the semantic features of the concepts in the object domain are more strongly intercorrelated than those in the action domain. Therefore, object concepts should be more resilient to mild damage within the conceptual system than action concepts. As the level of damage increases, however, the intercorrelated features would collapse en masse so that object concepts would be far more impaired than action concepts (for a discussion on the impact of high feature correlation on damage, see Mahon & Caramazza, 2009). Within this proposal, the category of object concepts as a whole (i.e., both living and nonliving thing concepts) may be disproportionately impaired compared to action concepts, or action concepts may be disproportionately impaired compared to object concepts, depending on the severity of damage. No object/action dissociation should, however, be found in two patients with similar levels of conceptual deficit.

The above discussion of some theories of conceptual knowledge organization highlights that the appropriate categories that should be investigated to provide evidence relevant to extant theories at least include the categories of living things (animals and/or plants), artifacts (tools and/or nonmanipulable artifacts), and actions. We are not aware of any neuropsychological study of patients presenting with a conceptual deficit that has contrasted within the same design these three categories of concepts. Among the numerous reports of a disproportionate conceptual impairment for living things compared to artifacts or among the less frequent reports of a disproportionate conceptual impairment for artifacts compared to living things that we are aware of, we have found none that formally assessed the status of action conceptual knowledge in the patients. One possible exception is the study by Ferreira, Giusiano, and Poncet (1997), which reported on three patients with a disproportionate conceptual deficit for animals compared to tools (their performance in both naming and comprehension tasks was worse for animals than for tools). The patients' performance in naming action photographs was also reported: Action naming was relatively spared in comparison with naming animals. This pattern suggested that concepts of tools and of actions patterned together in comparison with concepts of animals. However, no statistical contrast was reported between the naming of tools and of actions, and the comprehension of actions was not tested.

Furthermore, in all the studies that had focused on noun and verb processing, which we reviewed here above, the composition of the noun stimulus set, when it was specified, included object items from both the living and the nonliving categories in proportions that varied across the studies and, also, across the different tasks used within a

given study (e.g., Bak et al., 2006; Berndt et al., 1997; Daniele et al., 1994; Laiacona & Caramazza, 2004; Silveri, Perri, et al., 2003). Nonetheless, except in a few studies, which, however, reported only naming data (Bird, Howard, et al., 2000; Damasio & Tranel, 1993; De Bleser & Kauschke, 2003; Lu et al., 2002), the patients' performance across the various categories of nouns was not reported. Thus, in all these studies focusing on noun and verb processing, one cannot know whether, within the noun set and in both naming and comprehension, the patients' performance for the living and nonliving items showed a similar or a distinct pattern, nor whether each of the noun categories presented a similar or a distinct pattern compared to the verb set.

Conclusions

The view that the conceptual system may be organized along the "object/action" dimension has been based on reports of brain-damaged patients showing a disproportionate naming and/or comprehension deficit for one grammatical class of words—that is, nouns or verbs. According to this view, the double noun/verb dissociation in fact reflected an underlying segregation between object and action concepts within the conceptual system.

We have reviewed the single-case, multiple-case, and group studies of brain-damaged patients that have reported a noun or a verb grammatical category-specific deficit and concluded that very few, if any, of these studies provided appropriate evidence in support of this interpretation—none has described with an appropriate methodology a disproportionate conceptual deficit for either objects or actions.

Two points must be made clear, however, to avoid misunderstandings. First, with the exception of a small number of them (e.g., Bak & Hodges, 2003; Bak et al., 2006; Bird, Howard, et al., 2000; Marshall, Chiat, et al., 1996; Marshall, Pring, et al., 1996; McCarthy & Warrington, 1985; K. M. Robinson et al., 1996; White-Devine et al., 1996), the studies we have reviewed here did not have this purpose nor made such claim. Our conclusion therefore does not question the interpretation of the patterns of deficit provided in most studies, only the empirical generalization that some authors advanced on the basis of them (e.g., Bird, Howard, et al., 2000; Gainotti, 2004, 2006; Kable et al., 2005; Kable et al., 2002; Vigliocco et al., 2004). Second, we are not arguing that it is unlikely that a seemingly grammatical category-specific deficit originates from a conceptual impairment affecting one or the other category of objects more than actions or the reverse—future studies might provide convincing evidence for that. Instead our point is that no study that investigated impairments for nouns compared to verbs, and in particular no study that concluded to the existence of a disproportionate or selective *conceptual* impairment for nouns or verbs, provided what is widely considered today as standard evidence for a category-specific conceptual impairment—namely, evidence for a selective or a significantly disproportionate naming *and* comprehension impairment for one category of concepts, which cannot be ascribed to pre- or postsemantic or other task-specific processing difficulties with one category of stimuli or to uncontrolled stimulus variables (like concept familiarity or imageability).

In this respect, the cases of verb disproportionate deficits raise particular interpretative difficulties. Many authors agree, indeed, on the idea that verb processing is more demanding than noun processing, although the nature of the specific or higher demand of verb processing is still unclear. Mätzig and colleagues (2009) recently have reviewed studies with aphasic patients that have reported a noun/verb dissociation in the picture naming task. They found that disproportionate verb naming deficits were far more frequently reported than disproportionate noun naming deficits and that they tended to result in smaller differences between nouns and verbs than the differences found in the noun deficits—two features that were also present in the corpus of studies we have reviewed here (see Appendix). They then suggested that a large proportion of disproportionate verb naming deficits, those with small differences in performance (i.e., less than 30%) between nouns and verbs, may be due to

additional processing demands of verb production rather than being due to true word class differences. They pointed to the higher morphosyntactic complexity and the lower imageability of verbs as well as the higher interpretative demand of action pictures as possible sources of higher processing difficulty for verbs. We have also drawn attention to the fact that the use of static depictions of actions to probe verb/action naming and comprehension may account for a verb/action disproportionate deficit in patients with reduced executive resource (see, for evidence, d'Honincthun & Pillon, 2008). Actually, higher demand in executive control for verb than for noun processing has been frequently advanced as a possible source of a verb disproportionate deficit, especially in patients with degenerative brain disease (e.g., Cotelli et al., 2006, 2007; Grossman et al., 2008; Rhee et al., 2001; Silveri, Salvigni, et al., 2003). Rhee and colleagues (2001) and Silveri, Salvigni, and colleagues (2003) provided evidence for a significant correlation between a disproportionate deficit in verb naming (Silveri, Salvigni, et al., 2003) or verb comprehension (Rhee et al., 2001) and executive resource limitation in patients with dementia of Alzheimer's type and patients with the frontal variant of frontotemporal dementia (see also Grossman et al., 2008, for similar evidence with patients with amyotrophic lateral sclerosis). Rhee and colleagues (2001) and Silveri, Salvigni, and colleagues (2003) suggested that verb comprehension and naming may be more dependent than nouns on executive resources such as working memory, planning, selective attention, and inhibitory control, because verb processing requires one to access and manipulate a more elaborate set of semantic and linguistic information. More empirical studies are needed, however, to understand the nature of the executive components engaged in the retrieval and manipulation of information about verbs, including from static depictions of actions, in the various tasks commonly used to probe verb and noun processing.

We then argued that investigating the patterns of conceptual impairment in terms of the "noun/verb" or "object/action" dichotomy was not appropriate if the aim was to constrain theories of conceptual organization. More fine-grained distinctions should be made indeed within both the category of "objects" and the category of "actions". In two recent single-case studies (Pillon & d'Honincthun, 2011; Vannuscorps & Pillon, 2011), we assessed conceptual knowledge of objects (both living things and artifacts) and actions in two brain-damaged patients, G.C. and J.J.G., presenting with a conceptual deficit. In the case G.C. (Pillon & d'Honincthun, 2011), it first appeared that the concepts of concrete objects (i.e., mixed living things and artifacts) were disproportionately impaired compared to the concepts of actions. However, further evidence showed that only the concepts of living things among concrete objects were in fact disproportionately impaired compared to the concepts of actions and that, furthermore, the concepts of artifacts were not differentially impaired compared to the concepts of actions. In the case J.J.G. (Vannuscorps & Pillon, 2011), who was referred to us because of his important difficulties in understanding verbs, we first found no significant dissociation in his comprehension performance with verbs and nouns when the noun set comprised both living thing and artifact items. However, further testing then showed that the patient's comprehension of living things was spared while he had a conceptual deficit of similar severity for verbs (i.e., actions) and artifacts. Thus, G.C. had a disproportionate conceptual deficit for the concepts of living things compared to both the concepts of artifacts and actions, which were similarly and less impaired, whereas J.J.G. had a disproportionate conceptual deficit for both the concepts of artifacts and actions, which were similarly impaired, compared to the concepts of living things. These findings demonstrated that investigating conceptual deficits in brain-damaged patients by considering the "noun/verb" or "object/action" dichotomy may lead to fallacious conclusions. Furthermore, in these two cases, the results also showed that manipulable and nonmanipulable artifacts or actions were not differentially impaired, which suggested that the manipulability dimension was not the source of the double

dissociation presented by G.C. and J.J.G. between the concepts of living things, on one hand, and the concepts of artifacts and actions, on the other hand.

We hope that this review of the neuropsychological cases of grammatical category-specific deficits in relation to the issue of conceptual knowledge organization will encourage further studies of patients presenting with a conceptual impairment to investigate separately, within a controlled design, the patients' conceptual knowledge of various categories of objects (e.g., animals/plants, artifacts, tools) in comparison with various categories of actions (e.g., manipulation and nonmanipulation actions). We believe that such studies have the potential to give us new insights into the principles underlying the mental organization of conceptual knowledge.

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APPENDIX

Summary of the studies reporting a grammatical category-specific deficit

In the tables below, we report all the single-case, multiple-case, and group studies to our knowledge that documented a significant dissociation between nouns and verbs in single-word production and/or comprehension tasks. We divided these studies into three sections:

- Section 1 (Table A1) includes the studies that reported a pattern of grammatical category-specific deficit that was inconsistent across processing modalities. This first section is further subdivided into five parts according to the type of inconsistency: (a) The category-specific deficit is present only in production (comprehension is preserved or equally impaired for both categories); (b) the category-specific deficit is present only in comprehension (production equally impaired for both categories); (c) the most impaired category is different in production and comprehension; (d) the category-specific deficit in comprehension is present only with one type of stimulus (words, pictures, or words/pictures); (e) the pattern of category-specific deficit is not consistent across the spoken and the written modality of verbal production.
- Section 2 (Table A2) groups the studies that reported a pattern of grammatical category-specific deficit in one modality, (a) production or (b) comprehension, but did not report any data as regards noun and verb processing in the other modality.
- Section 3 (Table A3) includes the studies that reported a pattern of grammatical category-specific deficit that was consistent across processing modalities.

For each study, we report the performance of single patients or the averaged performance of a group of patients in noun/verb production and comprehension and for each modality in terms of percentage of correct responses. We extracted these data from the results reported in the experimental section of the study; however, sometimes we considered also data from the preliminary evaluation or case report if they were relevant to the understanding of the origin of the category-specific deficit.

For production, we only report here the data from the picture naming task, which was administrated in all the studies. (Thus we did not report the data from the naming to definition or video naming tasks administrated in few studies, e.g., Berndt et al., 1997; d'Honincthun & Pillon, 2008; Laiacona & Caramazza, 2004.) For comprehension, we report the data from three types of task. First, the word–picture matching task (WPM) or, when available, the word–picture verification task (WPV). Second, the picture and/or word association task, which consisted in presenting triplets of pictures and/or written words and asking the patient to show which ones were semantically related. Third, for several studies (Breedin et al., 1998; d'Honincthun & Pillon, 2008; G. Robinson et al., 1999; Shapiro & Caramazza, 2003a, 2003b; Shapiro et al., 2000; Zingeser & Berndt, 1988), we report (also under the heading of "word association"), the data from a "synonymous task"; in this task, the patient is asked to tell whether pairs of words are synonymous, or which are the two synonymous words among a triplet of words.

The studies may report the patients' performance with different sets of items, administered several times for replication, or at different time points, especially in the cases of degenerative disease. We choose to report these data as follows:

- For each study, we only report the data of the set(s) of items for which a significant difference between nouns and verbs was found. When this was the case for various sets of items, the data related to the various sets are reported on successive rows. However, in a number of studies (Berndt et al., 1997; Bird, Howard, et al., 2000; Breedin et al., 1998; Hillis & Caramazza, 1995b; Hillis et al., 2002; Hillis et al., 2003; Rapp & Caramazza, 2002; Shapiro & Caramazza, 2003b; Shapiro et al., 2000; Zingeser & Berndt, 1988, 1990), the picture naming and/or the word–picture matching/verification task included two sets of nouns matched with a single set of verbs, one set of nouns being matched with the verbs in base frequency, the other in cumulative frequency (e.g., tasks from Zingeser & Berndt, 1990). For these studies, we report the averaged score for the two sets of nouns.
- When a patient or a group was tested several times with the same task and item set for replication, we report the data corresponding to these different testing sessions under A1 (i.e., first administration of the task), A2 (i.e., second administration), and so on.
- When a patient or a group was tested at different time points, we report the data corresponding to each testing period under T1 (i.e., first time period of testing), T2, and so on. However, in these studies, the dissociation between nouns and verbs in production and/or in comprehension was not always significant at each time period. We decided to report here only the results of the time period where a significant dissociation was observed.

Table A1. *Patterns of grammatical category-specific deficit inconsistent across processing modalities*

		Production				*Comprehension*							
		Spoken		*Written*		*Spoken WPM/V*		*Written WPM/V*		*Picture association*		*Word association*	
Authors Case/group (Aetiology/syndrome)	*A/T*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Objects*	*Actions*	*Nouns*	*Verbs*
(a) The category-specific deficit is present only in production (comprehension is preserved or equally impaired for both categories)													
Noun deficit													
Bates et al., 1991													
Group of 7 Wernicke's aphasics		26*	33	—	—	76[a]	76[a]	—	—	—	—	—	—
Berndt et al., 1997													
H.F. (CVA)		48*	82	—	—	97	93	—	—	—	—	—	—
Bird, Howard, et al., 2000													
J.S. (Head injury)		83°	96	—	—	100	—	—	—	98	—	—	—
M.L. (CVA)		72*	93	—	—	90	—	—	—	90	—	—	—
De Renzi & di Pellegrino, 1995													
Mario (Aneurysm)		10*	88	8*	82	99	—	100	—	—	—	100	—
Hernandez et al., 2007													
L.P.M. (AD)[b]		39*	78	—	—	95	93	—	—	—	—	—	—
		24*	67										
Laiacona & Caramazza, 2004													
E.A. (HSE)		42*	82	44*	86	98[c]	100[c]			—	—	—	—
		22*	85										
Marshall, Chiat, et al., 1996/ Marshall, Pring, et al., 1996													
R.G. (CVA)		29*	64	—	—	67	65	65	—	—	—	—	—
Miceli et al., 1988													
A.E. (CVA)		29*	50	—	—	88	86	—	—	—	—	—	—
S.F. (Lobectomy)		69*	86	—	—	100	100	—	—	—	—	—	—
Miozzo et al., 1994													
A.L. (Angioma)		50*	79	44*	75	100	100	100	100	—	—	—	—
Silveri & Di Betta, 1997													
D.A. (PDD)	T1	25*	52	21*	44	87	89	77	89	—	—	—	—
	T2	35°	52	29*	52	77	89	89	98	—	—	—	—
E.O. (CVA)	T2	35*	66	—	—	100	100	—	—	—	—	—	—
Sörös et al., 2003													
J.P. (CVA)	A1	37*	56	—	—	100	—	—	—	—	—	—	—
	A2	33°	43										
	A3	29*	49										
Zingeser & Berndt, 1988													
H.Y. (CVA)		29*	62	44*	75	94	—	—	—	—	—	91	—
		42*	85										
Verb deficit													
Bates et al., 1991													
Group of 6 Broca's aphasics		70	47*	—	—	87[a]	87[a]	—	—	—	—	—	—
Berndt et al., 1997													
E.A. (CVA)		39	18*	—	—	93	87	—	—	—	—	—	—
F.M. (CVA)		92	70*	—	—	100	93	—	—	—	—	—	—
J.S. (CVA)		78	54*	—	—	100	87	—	—	—	—	—	—
L.R. (CVA)		93	40*	—	—	90	93	—	—	—	—	—	—
M.L. (CVA)		88	64*	—	—	93	93	—	—	—	—	—	—

(*Continued overleaf*)

Table A1. (Continued)

Authors *Case/group* *(Aetiology/syndrome)*	*A/T*	*Production*				*Comprehension*							
		Spoken		*Written*		*Spoken WPM/V*		*Written WPM/V*		*Picture association*		*Word association*	
		Nouns	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Objects*	*Actions*	*Nouns*	*Verbs*
Breedin et al., 1998													
C.N. (Aneurysm)		90	67*	—	—	—	—	—	—	—	—	87	87
E.W. (Aneurysm)		92	73*	—	—	—	—	—	—	—	—	100	93
F.O. (CVA)		97	73*	—	—	—	—	—	—	—	—	100	100
V.P. (CVA)		40	17*	—	—	—	—	—	—	—	—	67	60
Cotelli et al., 2006													
Patient 1 (PNFA)		49	13*	—	—	91[d]	98[d]			—	—	—	—
Patient 2 (PNFA)		95	52*	—	—	100[d]	100[d]			—	—	—	—
Group of 10 CBD		86	63*	—	—	99[d]	98[d]			—	—	—	—
Group of 10 PSP		79	57*	—	—	98[d]	98[d]			—	—	—	—
Hillis et al., 2006													
Group of 27 PNFA		78	65*	76	65*	—	—	—	—	92	91	91	91
Jonkers & Bastiaanse, 1998													
F.L. (CVA)		85	63*	—	—	—	100	—	—	—	—	—	—
T.B. (CVA)		88	37*	—	—	—	97	—	—	—	—	—	—
Kambanaros, 2008													
Group of 5 fluent aphasics		64	49*	—	—	100	99	—	—	—	—	—	—
Kim & Thompson, 2000													
Group of 7 agrammatics		93	71*	—	—	100	97	—	—	—	—	—	—
Kim & Thompson, 2004													
Group of 14 AD		97	87*	—	—	—	—	98	95	—	—	—	—
Laiacona & Caramazza, 2004													
M.R. (CVA)		90	70*	—	—	100[c]	100[c]			—	—	—	—
		93	63*										
Miceli et al., 1988													
A.M. (CVA)		69	25*	—	—	98	98	—	—	—	—	—	—
Shapiro & Caramazza, 2003a													
R.C. (CVA)		92	59*	—	—	—	—	—	—	—	—	69	87
Shapiro & Caramazza, 2003b													
H.G. (CVA)	A1	73	23*	—	—	100	70	100	100	—	—	81	69
	A2	75	27*										
		71	24*										
Silveri & Di Betta, 1997													
R.I. (CVA)	T1	96	75*	—	—	100	100	—	—	—	—	—	—
S.M. (CVA)	T1	75	33*	71	39*	98	98	98	98	—	—	—	—
	T2	94	71*	94	46*	100	100	—	—	—	—	—	—
Silveri, Perri, et al., 2003													
S.A. (CVA)	T1	70	14*	73	18*	100	100	100	85	—	—	—	—
		92	27*	96	42*	96	94	98	96	—	—	—	—
Silveri, Salvigni et al., 2003													
Group of 42 AD		75	63*	—	—	95	90	—	—	—	—	—	—
Group of 17 fv-FTD		70	52*	—	—	93	87	—	—	—	—	—	—
Yip et al., 2006													
Group of 4 CVA with EFI		94	87°	—	—	97	96						
(b) The category-specific deficit is present only in comprehension (production is equally impaired for both categories)													
Noun deficit													
Cotelli et al., 2006													
Group of 6 SD		39	37	—	—	80*[d]	88[d]			—	—	—	—

(*Continued overleaf*)

Table A1. (Continued)

Authors Case/group (Aetiology/syndrome)	A/T	Production				Comprehension							
		Spoken		Written		Spoken WPM/V		Written WPM/V		Picture association		Word association	
		Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Objects	Actions	Nouns	Verbs
(c) The most impaired category is different in production and comprehension													
Berndt et al., 1997													
H.Y. (CVA)		42*	67	—	—	97	63*	—	—	—	—	—	—
Hillis & Caramazza, 1995a													
E.B.A. (CVA)		10*	70	—	—	—	—	100	40*	—	—	—	—
		13*	73					97	47*				
Shapiro et al., 2000													
J.R. (CVA)		50*	83	—	—	—	—	—	—	—	—	81	50*
Yoon et al., 2005													
T.P. (CVA)		0*	70	—	—	—	—	94	86*	—	—	—	—
		20*	73										
		30*	77										
		49*	87										
(d) The category-specific deficit in comprehension is present only with one type of stimulus (words, pictures, or words/pictures)													
Noun deficit													
Bak & Hodges, 2003													
Group of 14 SD		—	—	—	—	—	—	—	—	80	82	76*	82
Verb deficit													
Bak & Hodges, 2003													
Group of 10 fv-FTD		—	—	—	—	—	—	—	—	95	84*	95	89
Bak et al., 2006													
Ind I (PSP dem)	T2	45	10*	—	—	90	53*	—	—	60	48	—	—
Ind II (PSP dem)	T1	90	55*	—	—	100	87	—	—	88	67*	—	—
d'Honincthun & Pillon, 2008													
J.B. (fv-FTD)	T3	63	24*	—	—	63	33*	—	—	—	—	67	75
												52	45
(e) The pattern of category-specific deficit is not consistent across the spoken and the written modality of verbal production													
Noun deficit													
Hillis et al., 2004													
Group of 7 fluent PPA		65*	79	40	31	—	—	—	—	—	—	—	—
Hillis et al., 2006													
Group of 16 SD		54*	64	40	44	—	—	—	—	64	65	41	48
Verb deficit													
Caramazza & Hillis, 1991													
H.W. (CVA)		56	22*	99	99	—	—	—	—	—	—	—	—
S.J.D. (CVA)		99	97	99	70*	—	—	—	—	—	—	—	—
Collina et al., 2001													
E.T. (CVA)		90	57*	100	100	—	—	—	—	—	—	—	—
Hillis et al., 2002													
A.T.N. (nonfluent PPA)	T1	100	50*	100	100	100	100	—	—	—	—	—	—
	T2	33	3*	90	90	—	—	—	—	—	—	—	—
H.M.S. (nonfluent PPA)	T1	100	83*	100	100	100	100	—	—	—	—	—	—
	T2	13	10	100	40*	—	—	—	—	—	—	—	—
M.M.L. (nonfluent PPA)	T1	88	60*	90	90	100	100	—	—	—	—	—	—
	T2	87	6*	92	92	—	—	—	—	—	—	—	—

(*Continued overleaf*)

Table A1. (Continued)

Authors Case/group (Aetiology/syndrome)	*A/T*	*Production*				*Comprehension*							
		Spoken		*Written*		*Spoken WPM/V*		*Written WPM/V*		*Picture association*		*Word association*	
		Nouns	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Objects*	*Actions*	*Nouns*	*Verbs*
Hillis et al., 2003													
Case 1 (CVA)		97	93	83	33*	99	100	—	—	—	—	—	—
Case 2 (CVA)		80	70	93	53*	99	100	—	—	—	—	—	—
Hillis et al., 2004													
Group of 15 nonfluent PPA		82	54*[e]	82	62*	—	—	—	—	—	—	—	—
Hillis et al., 2006													
Group of 13 ALS-FTD		66	58	77	71*	—	—	—	—	88	87	90	88
Marshall et al., 1998													
E.M. (CVA)		90	59*	90	83	100	99	—	—	—	—	—	—
Rapp & Caramazza, 1998													
P.W. (CVA)	T1	87	91	70	30*	—	—	—	—	—	—	—	—
	T2	80	80	78	17*	—	—	—	—	—	—	—	—
Both noun & verb deficit													
Rapp & Caramazza, 2002													
K.S.R. (CVA)		8*	37	70	23*	95	90	—	—	—	—	—	—

Note: *The category of words that was significantly the most impaired ($p < .05$). °The category of words that was the most impaired with marginal significance ($.05 < p < .1$). —Indicates that the corresponding data were not reported in the paper.

A/T: Administration number/Time period; AD: Alzheimer's disease; ALS-FTD: amyotrophic lateral sclerosis associated with frontotemporal dementia; CBD: corticobasal degeneration; CVA: cerebral vascular accident; EFI: executive function impairment; fv-FTD: frontal variant of frontotemporal dementia; HSE: herpes simplex virus encephalitis; PDD: progressive degenerative disease; PNFA: progressive nonfluent aphasia; PPA: primary progressive aphasia; PSP dem: progressive supranuclear palsy associated with dementia; SD: semantic dementia; WPM/V: word–picture matching or verification.

[a]The authors did not report separate scores for nouns and verbs but noted that there was no significant effect of grammatical class in comprehension. The scores reported here were those we averaged across nouns and verbs. [b]The patient was a bilingual speaker; we report here the results in the patient's first language. [c]We presumed that the modality of presentation of the stimuli was the spoken modality but the paper did not specify it. [d]The items were presented simultaneously in the spoken and written modality. [e]Verbs were more impaired than nouns in both spoken and written naming, but verbs were more impaired in spoken than written naming.

Table A2. *Grammatical category-specific deficit in production or comprehension only without data in the other modality*

Authors Case/group (Aetiology/syndrome)	A/T	Production				Comprehension							
		Spoken		Written		Spoken WPM/V		Written WPM/V		Picture association		Word association	
		Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Objects	Actions	Nouns	Verbs
(a) Grammatical category-specific deficit in production—no data in comprehension													
Noun deficit													
Bi et al., 2007													
Z.B.L (CVA)	T1	44*	76	—	—	—	—	—	—	—	—	—	—
	T2	41*	68	—	—	—	—	—	—	—	—	—	—
		37*	80										
Damasio & Tranel, 1993													
AN-1033 (Head injury)		57*	96	—	—	—	—	—	—	—	—	—	—
Boswell (HSE)		38*	92	—	—	—	—	—	—	—	—	—	—
Menichelli & Semenza, 2006													
B.L. (CVA)		34*	73	38*	68	—	—	—	—	—	—	—	—
Miceli et al., 1984													
Group of 5 anomics		42*	72	—	—	—	—	—	—	—	—	—	—
Silveri & Ciccarelli, 2007b													
Group of 7 SD		39*	62	39*	64	—	—	—	—	—	—	—	—
Williamson et al., 1998													
Group of 10 AD		56*	67	—	—	—	—	—	—	—	—	—	—
Verb deficit													
Arévalo et al., 2007													
Group of 10 anomics		70	60*	—	—	—	—	—	—	—	—	—	—
Group of 6 Broca's aphasics		65	45*	—	—	—	—	—	—	—	—	—	—
Group of 5 Wernicke's aphasics		48	39*	—	—	—	—	—	—	—	—	—	—
Bastiaanse & Jonkers, 1998													
Group of 8 agrammatics		42	29*	—	—	—	—	—	—	—	—	—	—
Group of 8 anomics		45	32*	—	—	—	—	—	—	—	—	—	—
Berndt & Haendiges, 2000													
J.H. (CVA)		80	47*	80	30*	—	—	—	—	—	—	—	—
Berndt et al., 2002													
A.M. (fluent aphasic)		85	61*	—	—	—	—	—	—	—	—	—	—
J.M. (fluent aphasic)		72	48*	—	—	—	—	—	—	—	—	—	—
M.L. (fluent aphasic)		89	56*	—	—	—	—	—	—	—	—	—	—
R.E. (nonfluent aphasic)		83	35*	—	—	—	—	—	—	—	—	—	—
S.C. (nonfluent aphasic)		70	37*	—	—	—	—	—	—	—	—	—	—
Bird, Howard, et al., 2000													
I.B. (CVA)		81	46*	—	—	—	—	—	—	—	—	—	—
		65	27*										
J.M. (CVA)		98	74*	—	—	—	—	—	—	—	—	—	—
		88	77*										
T.J. (CVA)		83	57*	—	—	—	—	—	—	—	—	—	—
		77	47*										
Breedin & Martin, 1996													
L.K. (CVA)		93	63*	—	—	—	—	—	—	—	—	—	—
V.P. (CVA)		40	17*	—	—	—	—	—	—	—	—	—	—

(*Continued overleaf*)

Table A2. (Continued)

Authors *Case/group* *(Aetiology/syndrome)*	*A/T*	*Production*				*Comprehension*							
		Spoken		*Written*		*Spoken WPM/V*		*Written WPM/V*		*Picture association*		*Word association*	
		Nouns	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Objects*	*Actions*	*Nouns*	*Verbs*
Cappa et al., 1998													
Group of 10 FTD		81	59*	—	—	—	—	—	—	—	—	—	—
Collina et al., 2001													
P.R. (CVA)		90	46*	82	45*	—	—	—	—	—	—	—	—
M.N. (Aneurysm)		93	68*	95	68*	—	—	—	—	—	—	—	—
Cotelli et al., 2007													
A group of 32 PD		90	65*	—	—	—	—	—	—	—	—	—	—
Crepaldi et al., 2006													
Group of 16 aphasics		73	35*	—	—	—	—	—	—	—	—	—	—
Damasio & Tranel, 1993													
KJ-1360 (left premotor lesion)		91	53*	—	—	—	—	—	—	—	—	—	—
De Bleser & Kauschke, 2003													
Case 2F (fluent aphasic)		97	42*	—	—	—	—	—	—	—	—	—	—
Case 3F (fluent aphasic)		94	58*	—	—	—	—	—	—	—	—	—	—
Group of 5 nonfluent aphasics		90	47*	—	—	—	—	—	—	—	—	—	—
Group of 2 global aphasics		42	14*	—	—	—	—	—	—	—	—	—	—
Hillis et al., 2004													
Group of 6 ALS-FTD		57	42*	71	56*	—	—	—	—	—	—	—	—
Lu et al., 2002													
Group of 15 LATL		92	83*	—	—	—	—	—	—	—	—	—	—
Group of 15 RATL		96	90*	—	—	—	—	—	—	—	—	—	—
Luzzatti et al., 2002													
Group of 6 agrammatics		71	33*	—	—	—	—	—	—	—	—	—	—
Mätzig et al., 2009													
Group of 9 aphasics		91	78*[a]	—	—	—	—	—	—	—	—	—	—
Miceli et al., 1984													
Group of 5 agrammatics		65	57*	—	—	—	—	—	—	—	—	—	—
K. M. Robinson et al., 1996													
Group of 20 AD		64	48*	—	—	—	—	—	—	—	—	—	—
Silveri & Ciccarelli, 2007a													
Case 1 (CBD)		75	36*	—	—	—	—	—	—	—	—	—	—
Case 2 (CBD)		66	36*	—	—	—	—	—	—	—	—	—	—
Case 3 (CBD)		80	30*	—	—	—	—	—	—	—	—	—	—
Case 4 (CBD)		68	42*	—	—	—	—	—	—	—	—	—	—
Case 5 (CBD)		74	38*	—	—	—	—	—	—	—	—	—	—
Silveri & Ciccarelli, 2007b													
Group of 30 fv-FTD		87	67*	—	—	—	—	—	—	—	—	—	—
Group of 14 nonfluent PPA		80	64*	77	70*	—	—	—	—	—	—	—	—
Zingeser & Berndt, 1990													
Group of 5 agrammatics		85	57*	—	—	—	—	—	—	—	—	—	—

(*Continued overleaf*)

Table A2. (Continued)

Authors Case/group (Aetiology/syndrome)	A/T	Production				Comprehension							
		Spoken		Written		Spoken WPM/V		Written WPM/V		Picture association		Word association	
		Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Objects	Actions	Nouns	Verbs
(b) Grammatical category-specific deficit in comprehension—no data in production													
Verb deficit													
Grossman et al. (2008)													
Group of 34 ALS		—	—	—	—	—	—	98[b]	88*[b]	—	—	94	92
Rhee et al. (2001)													
Group of 21 FTD		—	—	—	—	—	—	88	79*	—	—	—	—

Note: *The category of words that was significantly the most impaired ($p < .05$). —The corresponding data were not reported in the paper.

A/T: Administration number/Time period; AD: Alzheimer's disease; ALS: amyotrophic lateral sclerosis; ALS-FTD: amyotrophic lateral sclerosis associated with frontotemporal dementia; CBD: corticobasal degeneration; CVA: cerebral vascular accident; fv-FTD: frontal variant of frontotemporal dementia; FTD: frontotemporal dementia; HSE: herpes simplex virus encephalitis; LATL: left anterior temporal lobectomy; PD: Parkinson's disease; PPA: primary progressive aphasia; RATL: right anterior temporal lobectomy; SD: semantic dementia; WPM/V: word–picture matching or verification.

[a]Logistic regression analyses performed on the data of each patient in the group revealed that, in every patient, grammatical class had no significant effect on the accuracy score once several variables were controlled for. [b]The task was a word-to-description matching task and comprised verbal stimuli only; the patient had to choose among four words the one that best matched a verbal description of an action or an object. We presumed that the modality of presentation of the stimuli was the written modality but the paper did not specify it. Note also that the statistical analysis was based on the average of the patients' percentage accuracy scores obtained in the two comprehension tasks.

Table A3. *Patterns of grammatical category-specific deficit that are consistent across processing modalities*

Authors Case/group (Aetiology/syndrome)	A/T	Production				Comprehension							
		Spoken		Written		Spoken WPM/V		Written WPM/V		Picture association		Word association	
		Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns	Verbs	Objects	Actions	Nouns	Verbs
Noun deficit													
Daniele et al., 1994													
G.P. (FDP)	T1	7*	36	—	—	—	—	—	—	—	—	—	—
	T2	4	17	—	—	42°[a]	60[a]	—	—	—	—	—	—
Miceli et al., 1988													
A.A. (HSE)	A1	46*	64	—	—	88*	100	—	—	—	—	—	—
	A2					90°	98						
Parris & Weekes, 2001													
R.S. (Dementia)		15*	100	—	—	50*	100	—	—	—	—	—	—
						45*							
G. Robinson et al., 1999													
A patient with AD		17*	80	—	—	—	—	—	—	—	—	62*	85
Silveri, Perri, et al., 2003													
C.G. (SD)	T5	23*	53	—	—	85*	98	—	—	—	—	—	—

(*Continued overleaf*)

Table A3. (Continued)

		Production				*Comprehension*							
		Spoken		*Written*		*Spoken WPM/V*		*Written WPM/V*		*Picture association*		*Word association*	
Authors Case/group (Aetiology/syndrome)	*A/T*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Nouns*	*Verbs*	*Objects*	*Actions*	*Nouns*	*Verbs*
Verb deficit													
Bak et al., 2001													
Group of 6 MND		57	31°	—	—	86	63*	—	—	—	—	—	—
Cotelli et al., 2006													
Group of 10 AD		78	65*	—	—	98[b]	92*[b]			—	—	—	—
Group of 16 fv-FTD		68	59*	—	—	98[b]	88*[b]			—	—	—	—
Daniele et al., 1994													
R.A. (FDP)	T2	96	65*	92	52*	100	92°	—	—	—	—	—	—
	T3	31	4*	—	—	96	75*	—	—	—	—	—	—
G.G. (SRO/PSP)	T1	94	69*	—	—	100	92°	—	—	—	—	—	—
	T2	96	77*	—	—	100	83*	—	—	—	—	—	—
Hernandez et al., 2008													
J.P.G. (nonfluent PPA)[c]	T1	86	67°	81	50*	—	—	—	—	—	—	—	—
	T2	80	59°	76	38*	—	—	97	75*	—	—	—	—
	T3	77	48*	86	20*	—	—	—	—	—	—	—	—
	T4	87	41*	96	25*	—	—	94	78*	—	—	—	—
	T5	34	12°	70	15*	—	—	86	72*	—	—	—	—
Kim & Thompson, 2004													
Group of 9 agrammatics		90	76*	—	—	—	—	97	94*	—	—	—	—
McCarthy & Warrington, 1985													
R.O.X. (PDD)	A1	—	43	—	—	100	80*	—	—	—	—	—	—
			43			95	55*						
			30										
	A2					98	68*						
						83	63*						
Miceli et al., 1988													
C.S. (CVA)	A1	83	36*	—	—	98	84*	—	—	—	—	—	—
	A2					100	86*						
F.D.P. (CVA)	A1	96	78*	—	—	100	84*	—	—	—	—	—	—
	A2					100	90*						
White-Devine et al., 1996													
Group of 21 AD		59	52*	—	—	—	—	78	71*	—	—	—	—

Note: *The category of words that was significantly the most impaired ($p < .05$). °The category of words that was the most impaired with marginal significance ($.05 < p < .1$). —The corresponding data were not reported in the paper.

A/T: Administration number/Time period; AD: Alzheimer's disease; CVA: cerebral vascular accident; FDP: focal degenerative pathology; fv-FTD: frontal variant of frontotemporal dementia; HSE: herpes simplex virus encephalitis; MND: motor neuron disease; PDD: progressive degenerative disease; PPA: primary progressive aphasia; SD: semantic dementia; SRO/PSP: Steele–Richardson–Olszewski syndrome or progressive supranuclear palsy; WPM/V: word–picture matching or verification.

[a]The scores reported in the original paper were 54% of errors for nouns and 12% of errors for verbs (Daniele et al., 1994, Table 3, p. 1333). However, these percentages of errors did not include the "don't know" responses, which were far less frequent in the case of nouns (4%) than verbs (28%). The percentage of correct responses we report here were calculated by including the "don't know" responses in the total of erroneous responses (which thus amounted to 58% for nouns and 40% for verbs). [b]The items were presented simultaneously in the spoken and written modality. [c]The patient was a bilingual speaker; we report here the results in the patient's first language.