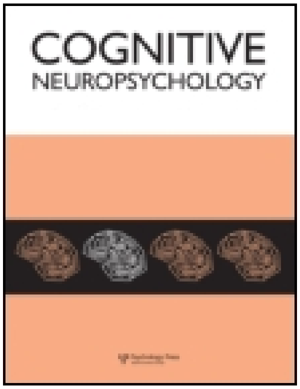

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A common processing system for the concepts of artifacts and actions? Evidence from a case of a disproportionate conceptual impairment for living things

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A common processing system for the concepts of artifacts and actions? Evidence from a case of a disproportionate conceptual impairment for living things

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We report the results of a single-case study carried out with a brain-damaged patient, G.C., whose conceptual knowledge of living things (animals and plants) was significantly more impaired than his knowledge of artifacts and his knowledge of actions, which were similarly impaired. We examined whether this pattern of conceptual impairment could be accounted for by the "sensory/functional" or the "manipulability" account for category-specific conceptual impairments advocated within the feature-based organization theory. To this end, we assessed, first, the patient's knowledge of sensory compared to functional and motor features and, second, his knowledge of nonmanipulable compared to manipulable items. The findings showed that the patient's disproportionate impairment for living things compared to both artifacts and actions was not associated with a disproportionate impairment of sensory compared to functional or motor knowledge or with a relative sparing of manipulable compared to nonmanipulable items. We then discuss how alternative theories of conceptual knowledge organization could account for G.C.'s pattern of category-specific deficit.

Keywords: Conceptual system; Category-specific deficits; Concepts of actions; Sensory–functional account; Manipulability.

It is now well known that brain damage may impair conceptual knowledge of concrete objects and also that knowledge of one category of objects, like animals, fruit and vegetables (plant life), or artifacts may selectively or disproportionately be impaired compared to knowledge of another category (for a review, see Capitani, Laiacona, Mahon, & Caramazza, 2003). During the last three decades, such patterns of category-specific conceptual impairment have provided an important source of

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evidence allowing the development of theories of the organization of conceptual knowledge in the human mind and brain (e.g., Caramazza & Shelton, 1998; Humphreys & Forde, 2001; Martin, Ungerleider, & Haxby, 2000; Simmons & Barsalou, 2003; Warrington & McCarthy, 1987). However, one limitation of both neuropsychological studies and theoretical debates during these decades was that they mainly focused on object concepts, while additional evidence and a more complete picture could be drawn from studying patterns of conceptual impairment affecting other classes of concepts—for example, action concepts. The term "action concepts" or "actions" refers here to categories of human purposeful activities like those expressed by a single verb (e.g., *drinking* or *grating*). It does not refer to body movements (e.g., raising the arm) or more specific activities like the ones expressed by verbal phrases (e.g., *drinking wine* or *grating cheese*). By "action conceptual knowledge", we mean the different types of knowledge acquired about categories of human purposeful activities, such as their causes and consequences, the objects, people, and instruments they generally involve, the typical context in which they take place, their emotional content, and so on.

We show here that insight into the principles of organization of conceptual knowledge could be gained by asking how knowledge of each category of objects—that is, knowledge of living things (animals and/or plants) and knowledge of nonliving things (artifacts)—is respectively related to knowledge of actions at the functional and neural level; by asking, in other words, how these three categories of concepts may pattern following damage to the conceptual system.

There is to date little if any available evidence relevant to this issue. 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 whose performance in both naming and comprehension tasks was worse for animals than for tools. These three patients' performance in naming action photographs was also reported and indicated that action naming was relatively spared in comparison with naming animals. This pattern suggested that the concepts of tools and actions (both spared) patterned together in comparison with the concepts of animals (impaired) in case of damage to the conceptual system. However, no statistical contrast was reported between the naming performance for tools and actions, and the three categories of items (animals, tools, actions) were not controlled for any possible confounding variable like name frequency or concept familiarity.

On the other hand, there have been numerous reports of patients showing, in naming and/or comprehension tasks, a selective or disproportionate deficit for nouns in comparison with verbs or the reverse (for reviews, see Druks, 2002; Mätzig, Druks, Masterson, & Vigliocco, 2009; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011). Because in almost all these reports, the naming and comprehension tasks included concrete nouns and concrete verbs, which correspond to physical objects and actions, respectively, 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, Lease-Spellmeyer, & Chatterjee, 2002; Laiacona & Caramazza, 2004; Silveri, Perri, & Cappa, 2003; Vigliocco, Vinson, Lewis, & Garrett, 2004) or in every case (Bird, Howard, & Franklin, 2000), the noun/verb dissociation in fact reflected an underlying conceptual deficit selectively or disproportionately affecting either object or action concepts (for a critical review of these cases, see Pillon & d'Honincthun, 2010). However, in all these studies, the composition of the noun stimulus set, when it was specified, included object items from both the living and 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, Mitchum, Haendiges, & Sandson, 1997; Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Laiacona & Caramazza, 2004; Silveri et al., 2003). Nonetheless, except in a few studies, which, however, reported only naming data (Bird 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 (object) set and in both naming and comprehension, each of the noun (object) categories—that is, the living and nonliving item set—presented a similar or a distinct pattern compared to the verb (action) set.[1]

In the single-case study we report here, we sought empirical evidence pertaining to the issue of the functional relations between conceptual knowledge of living things and of artifacts compared to conceptual knowledge of actions, by assessing knowledge of these three categories of concepts in a brain-damaged patient presenting with a conceptual deficit. The second aim was to find evidence in the patient's pattern of conceptual deficit that could inform the theoretical issue of which are the organizing principles of conceptual knowledge in brain in mind. Extant theories of the representation of conceptual knowledge indeed make specific assumptions on the principal determinant of the organization of conceptual knowledge, from which distinct predictions follow as regards, first, the patterns of conceptual impairment that may show up when categories of living things, artifacts, and actions are considered and, second, the specific types of conceptual knowledge that should be impaired/spared when a given semantic category is disproportionately impaired/spared compared to the others.

The currently dominant view on conceptual knowledge organization in the brain, which we call here the feature-based organization (FBO) theory, assumes that a concept 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; Cree & McRae, 2003; Humphreys & Forde, 2001; Martin et al., 2000; Patterson, Nestor, & Rogers, 2007; Vigliocco et al., 2004; Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984).[2] Within this theoretical framework, 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. The differential weighting of features reflects the relative importance of the various types of conceptual properties within the definition of a given concept (Farah & McClelland, 1991; Warrington & McCarthy, 1983; Warrington & Shallice, 1984) or the relative involvement of the various sensori-motor modalities of experience during the acquisition of that concept (Allport, 1985; Crutch & Warrington, 2003; Damasio &

[1]There is another series of neuropsychological studies that could be mentioned here: those that reported a pattern of poorer naming of visually presented objects (living and/or nonliving things) than of actions (but not the reverse) in patients presenting the so-called "optic aphasia" (for a review, see Gainotti, 2004). However, in these cases, the functional locus of the disproportionate naming impairment for objects compared to actions was likely not the conceptual system. Naming objects was only or most impaired when probed from visual input, while naming from other input modalities (e.g., tactile exploration or verbal description) was relatively spared; also, in most cases, the comprehension of objects was spared or far better than naming. Therefore, these patterns are more relevant to the issue of the processing pathways and components involved in accessing conceptual knowledge for objects versus actions from vision than to the issue of the representation of conceptual knowledge for objects and actions itself.

[2]We included the "distributed-plus-hub" theory (Patterson et al., 2007) and the "featural and unitary semantic space" (FUSS) theory (Vigliocco et al., 2004) within the FBO framework because both these theories assume a level of conceptual representations organized by kind of feature. However, the "distributed-plus-hub" theory (Patterson et al., 2007) further assumes a "conceptual hub", connected to the distributed featural representations, which represents unified, amodal, representations for all categories of objects, and the FUSS theory (Vigliocco et al., 2004) further assumes a level of "lexico-semantic" representations that binds the featural representations into word meanings and whose internal organization emerged from featural statistical properties (cf. infra).

Tranel, 1993; Gainotti, Silveri, Daniele, & Giustolisi, 1995; Warrington & McCarthy, 1987).

In this theoretical context, Bird et al. (2000) extended the "sensory/functional" hypothesis formerly advanced by Warrington and McCarthy (1983), by assuming that the concepts of living things have a greater weighting of sensory than functional features, whereas both the concepts of artifacts and the concepts of actions have a greater weighting of functional than sensory features (although the concepts of artifacts have a lower functional/sensory ratio than the concepts of actions). On this basis, selective damage to functional 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 selectively or disproportionately impair the concepts of living things compared to both the concepts of artifacts and the concepts of actions. Another proposal advanced within the FBO theoretical framework emphasized the primary role of a more specific sensorimotor dimension—that is, manipulability—in determining the organization of conceptual knowledge (e.g., Gerlach, Law, & Paulson, 2002; Kellenbach, Brett, & Patterson, 2003; Noppeney, Josephs, Kiebel, Friston, & Price, 2005; Saccuman et al., 2006). According to this view, whether the utilization of an object (plant or artifact) involves fine hand movements or not (i.e., whether it is a manipulable or a nonmanipulable object) or whether an action involves fine hand motion or the whole body, is a crucial conceptual feature determining how (and where in the brain) the corresponding concepts are processed and represented. Thus, conceptual representations of both artifacts and actions that are weighted for manipulation features would mainly rely on a manipulation knowledge system (see also Buxbaum & Saffran, 2002). In the case of selective damage (or selective sparing) to this system, the expected pattern of separation thus would be between the concepts that are differentially weighted for manipulation features—that is, on the one hand, both manipulable artifacts and manipulation actions and, on the other hand, living things and both artifacts and actions that do not involve manipulation. Whatever the proposal made within the FBO theory, however, it is expected that any category-specific conceptual deficit should be associated with a feature-specific conceptual deficit—that is, a disproportionate deficit for the type of feature (visual, functional, manipulability) that is assumed to be crucial in the processing of the disproportionately impaired category.

In contrast, within an alternative theoretical approach to conceptual knowledge organization, which we call here the correlated and unitary content (CUC) approach, a selective deficit to a semantic category should equally affect all types of knowledge related to that category, and, furthermore, random damage to the conceptual system would not be likely to impair the concepts of artifacts and of actions at the same time.

Within the CUC approach, the conceptual system is viewed as a distributed network containing the conceptual features of all categories of objects or actions without any explicit boundary according to category or type of feature. Within this unitary space of conceptual features, however, some internal structure emerges as a result of a differential distribution of conceptual feature properties across the various categories of concepts. Several proposals were made within this general approach. The "organized unitary content" hypothesis (OUCH; Caramazza, Hillis, Rapp, & Romani, 1990; see also Caramazza & Shelton, 1998) and the "featural and unitary semantic space" theory (FUSS; Vigliocco et al., 2004) both assumed that, because members of a given category share many properties in common, which are highly intercorrelated (i.e., often activated together), the conceptual features of members of a category tend to cluster together within the conceptual space and, hence, are susceptible to selective damage.[3] Within the domain

[3]Within the "featural and unitary semantic space" (FUSS) theory (Vigliocco et al., 2004), it is the level of "lexico-semantic" representations that is organized according to these principles.

of concrete objects, 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 (Cree & McRae, 2003; Garrard, Lambon Ralph, Hodges, & Patterson, 2001; Small, Hart, Nguyen, & Gordon, 1995; Vigliocco et al., 2004). When the conceptual features of object and action concepts are considered within the same cluster analysis (Vigliocco et al., 2004), the results showed that members of the object domain are largely segregated from those of the action domain. On this basis, one can predict that random damage to the conceptual space could result in a selective deficit or preservation of any category of object concepts (animate livings, inanimate livings, artifacts, or even a finer grained category within the living or the artifact category) or of the whole category of actions—but less likely in a selective deficit or preservation of both artifact and action concepts.

Other proposals within the CUC approach, like the computational model of Devlin, Gonnerman, Andersen, and Seidenberg (1998) and the "conceptual structure account" (CSA) of Tyler and colleagues (Taylor, Moss, & Tyler, 2007; Tyler & Moss, 2001), assumed that the extent to which features are shared by different concepts or distinctive of a given concept, and the frequency with which these features co-occur with other features, are important dimensions that structure the conceptual space and that could predict which conceptual category would be more resilient to damage to the conceptual system. It is assumed that correlated conceptual 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. The only analysis of speaker-generated features contrasting the object and action domains that is available to date (Vinson, Vigliocco, Cappa, & Siri, 2003) indicated that the concepts of living things have more correlated features than the concepts of artifacts, which have themselves more correlated features than the concepts of actions, although the three categories of concepts did not differ in the number of shared features. Within Devlin and colleagues' model, this difference in feature correlation across the categories of concepts should make the concepts of living things *and* artifacts more resilient to mild damage within the conceptual system than the concepts of actions but, as the level of damage increases, the intercorrelated features would collapse en masse so that living thing *and* artifact concepts would be far more impaired than action concepts (for a discussion on these assumptions regarding the impact of high feature correlation on damage, see Mahon & Caramazza, 2009). In other words, within this model, whatever the severity, random damage to the conceptual network is the most likely to result in a dissociation between the concepts of artifacts and of actions, contrary to what it is predicted within the FBO theory, where both categories should pattern together. The same prediction would, however, not necessarily follow from the assumptions made within CSA (Taylor et al., 2007). This theory assumes that the category with the higher correlations between *distinctive* (as opposed to shared) features would be the less impaired in the case of brain damage, because distinctive, more than shared, features are important for the unique identification of a given concept. Because the concepts of artifacts are characterized by stronger correlations between their distinctive properties than the concepts of living things (Randall, Moss, Rodd, Greer, & Tyler, 2004), the concepts of artifacts should be more resistant to damage than those of living things, contrary to the predictions based on Devlin et al.'s (1998) model. However, in the only available study of feature distribution in the object and action domain (Vinson et al., 2003), the number of correlated distinctive features was not computed in the action domain. Therefore, no prediction could be drawn from CSA to date about how the concepts of artifacts and the concepts of actions should pattern after brain damage.

Finally, a third influential view on conceptual knowledge organization can be mentioned here, namely, the domain-specific knowledge systems (DSK) theory (Caramazza & Shelton, 1998; Mahon & Caramazza, 2009, 2011). This theory assumes that evolutionary pressures led to specific adaptations consisting in specialized perceptual and cognitive processes and dedicated domain-specific neural circuits for processing knowledge of conspecifics, animals, plant life, and, within the broader category of artifacts, tools—four domains in which quick and efficient recognition are thought to have fitness value. The theory thus predicts that each of these four categories of concepts could be selectively impaired or spared in the condition of brain damage and, also, that damage to a category will equally affect all types of knowledge about that category. It is silent, however, about the kind of processing system that would sustain conceptual knowledge of artifacts other than tools and of actions and how such knowledge would be organized. Therefore, like CSA, in its present state of elaboration, this theory does not allow us to draw specific predictions about how the concepts of artifacts and of actions should pattern following brain damage.

In what follows, after a detailed case report, we present the results of the experimental study carried out with a brain-damaged patient, G.C., whose conceptual knowledge of living things was significantly more impaired than his knowledge of artifacts and his knowledge of actions, which were similarly impaired. We thus examined whether this pattern of conceptual impairment could be accounted for by, first, the "sensory/functional" (Bird et al., 2000) and, second, the "manipulability" (e.g., Gerlach et al., 2002; Kellenbach et al., 2003; Noppeney et al., 2005; Saccuman et al., 2006) account for category-specific conceptual impairments advocated within the FBO theoretical framework. To this end, we assessed (a) the patient's knowledge of sensory compared to functional and motor features and (b) his knowledge of nonmanipulable compared to manipulable items. The findings showed that, contrary to the predictions made by the "sensory/functional" and the "manipulability" accounts for category-specific conceptual impairments, the patient's disproportionate impairment for living things compared to both artifacts and actions was not associated with a disproportionate impairment of sensory compared to functional or motor knowledge or with a relative sparing of manipulable compared to nonmanipulable items. The ability of alternative theories of conceptual knowledge organization to account for this pattern of category-specific conceptual deficit is then addressed in the general discussion.

CASE REPORT

G.C. was a right-handed man (born 1957) with a Master's Degree in Architecture who worked in an insurance company when, in 1994, he contracted herpes simplex virus encephalitis, which left him with extensive brain damage, mainly on the left side. No other neurological or neuropsychological data were available at that time. Magnetic resonance imaging (MRI) performed in September 2006 showed an almost complete destruction of the left temporal lobe, only a posterior part of the superior temporal gyrus being partially preserved. A large part of the left insula was destroyed, and there was a discrete lesion of the inferior border of the left rolandic operculum, the majority of the inferior frontal gyrus being preserved. The lesion extended to the left occipital lobe, involving the middle and inferior occipital gyri, the fusiform gyrus, and the anterior part of the lingual gyrus with a small extension to the anterior border of the calcarine fissure. The left intraparietal sulcus and the inferior parietal lobule were preserved with only some gliosis in the white matter at the base of the angular gyrus extending to the parieto-occipital fissure. On the right side, damage was less extensive and concerned only the temporal lobe, involving mainly the entorhinal cortex, the parahippocampal and fusiform gyri, and the amygdala. There was also a focal destruction of the anteromedial part of the superior temporal gyrus and of the anterior part of the inferior temporal gyrus (Figure 1).

Ten years post onset, in September 2004, the patient presented himself for language rehabilitation at the Cliniques universitaires Saint-Luc,

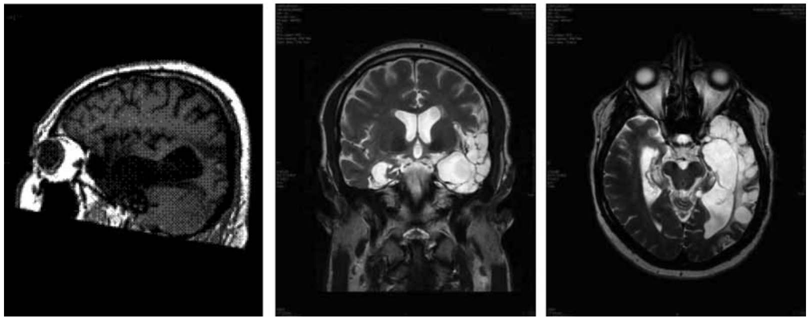

Figure 1. *Magnetic resonance imaging (MRI) scan of patient G.C. Sagittal, coronal, and transversal views.*

Brussels, with the complaint of persistent word-finding and, especially, comprehension difficulties that impeded his participation in conversations with friends. He then volunteered to participate in this study. The neuropsychological examinations (see Table 1) performed at that time identified a severe impairment in visual episodic memory (verbal episodic memory could not be tested because of the semantic deficit). However, short-term memory, both verbal and spatial, was spared, as well as executive functions. There was no sign of frontal dysfunction, either in formal testing or in social behaviour. Numerical knowledge and processing (i.e., counting, transcoding, accessing quantity, retrieving arithmetical facts, and performing complex calculations) were also spared.

Visual processing assessed with the Birmingham Object Recognition Battery (BORB; Riddoch & Humphreys, 1993) was spared, except in two subtests of the object decision task. However, this task includes mainly drawings of real/unreal animals (88% of the items), with which G.C. seemed to have particular difficulties. Actually, in the object decision task from the *Batterie de Décision Visuelle d'Objets* (Bergego, Pradat-Diehl, & Ferrand, 2006), G.C.'s overall performance was only slightly below that of the controls (63/72, 88%; controls: 68/72, 94%), and it was at ceiling (43/44, 98%) for the artifact items (furniture, vehicles, buildings, clothing, musical instruments, tools, etc.) and poorer for the animal items (20/28, 71%). In an object decision task including four subcategories of items—that is, animals, fruit/vegetables, vehicles, and implements (Samson, Pillon, & De Wilde, 1998)—G.C.'s overall performance was impaired compared to that of the controls (51/72, 71%; controls: 68/72, 94%, range: 65–72) and turned out to be very poor for both animals (11/18, 61%) and fruit/vegetables (9/18, 50%), while his performance for both vehicles (14/18, 78%) and implements (17/18, 94%) was good. Overall, these results indicated that G.C. probably presented with a category-specific structural processing impairment for living things (both animals and fruit/vegetables), while structural processing of various categories of artifacts was within the normal range.

Language examination (see Table 2) disclosed the characteristics of transcortical sensory aphasia. Spontaneous speech was fluent but not informative, with frequent word-finding difficulties in the context of correct articulation, prosody, and syntax. Repetition of syllables, words, nonwords, and sentences was also preserved. Moreover, the patient's performance in an auditory and a visual lexical decision task was within the normal range. The patient presented, however, severe anomia and speech comprehension difficulties. In a picture naming test, he correctly named only 9 out of 35 items (the erroneous responses were mainly circumlocutions, semantic paraphasias, and nonresponses), and his performance in a spoken-word-to-picture matching test was very poor (the patient's errors mainly consisted in choosing the semantically related foil). Finally, examination of G.C.'s reading and writing disclosed surface dyslexia and dysgraphia.

Table 1. *Neuropsychological data of patient G.C.*

Test	*G.C.'s score*	*G.C.'s z score or percentile (P)*
Short-term memory		
Digit Span		
Forward[a]	5	−1.37
Backward[a]	5	0.48
Spatial Span (Block Tapping Test)[b]	6	P = 75
Long-term memory		
Doors Test (Doors and People Test)[c]		
Part A	4/12	P < 1
Part B	interrupted	
Executive functions		
Stroop Test		
Naming		
Time (s)	78	−1.36
Self-corrected errors	0	0.84
Uncorrected errors	0	n.a.
Reading		
Time (s)	56.5	−1.83
Interference		
Time (s)	132	−0.75
Self-corrected errors	3	−1.37
Uncorrected errors	0	n.a.
Trail Making Test		
Part A		
Time (s)	31	0.65
Errors	0	0.42
Part B		
Time (s)	83	−0.08
Errors	0	0.3
Fluency		
Category fluency (Animals)	10	−3.05
Letter fluency (P)	24	−0.18
Copy of Rey Figure[d]		
Accuracy	32/36	P = 50
Organization	Type I	
Number processing		
Counting (from 1 to 21)		
Aloud	Correct	n.a.
Arabic numbers	Correct	n.a.
Transcoding		
Spoken numerals to arabic numbers	16/16	n.a.
Written numerals to arabic numbers	16/16	n.a.
Arabic numbers to spoken numerals	16/16	n.a.

Table 1. (Continued)

Test	*G.C.'s score*	*G.C.'s z score or percentile (P)*
Magnitude comparisons		
Arabic numbers	16/16	n.a.
Spoken numerals	16/16	n.a.
Written numerals	16/16	n.a.
Arithmetical facts		
Addition	18/18	n.a.
Subtraction	18/18	n.a.
Multiplication	18/18	n.a.
Division	18/18	n.a.
Complex calculations (arabic)		
Addition	2/2	n.a.
Subtraction	2/2	n.a.
Multiplication	1/2	n.a.
Visual processing		
BORB[e]		
Size match	29/30	0.70
Orientation match	28/30	1.23
Position of gap match	39/40	0.87
Minimal feature view	23/25	−0.15
Foreshortened view	25/25	1.31
Associative match	31/32	1.46
Object decision	90/128	−4.33
Dissimilar easy	*26/32*	*−1.20*
Dissimilar hard	*20/32*	*−3.18*
Similar easy	*23/32*	*−5.35*
Similar hard	*21/32*	*−0.94*
Batterie de Décision d'Objets[f]		
Animals	20/28	n.a.
Artifacts	43/44	n.a.
Total	63/72	68/72

Note: From examinations carried out in September 2004. n.a. = not available. BORB = Birmingham Object Recognition Battery.
[a]Wechsler (2000). [b]Smirni, Villardita, and Zappala (1983). [c]Baddeley, Emslie, and Nimmo-Smith (1994). [d]Rey (1959). [e]Riddoch and Humphreys (1993). [f]Bergego, Pradat-Diehl, and Ferrand (2006).

G.C.'s pattern of performance in the language tasks indicated that he presented with a semantic/conceptual deficit. His conceptual knowledge was further assessed for objects and actions in a semantic association task designed in two versions, that is, with pictures or written words. The task was the French translation of the "Pyramids and Palm Trees Test" (PPT, Howard & Patterson,

Table 2. *Results of the language evaluation of patient G.C.*

Test	*G.C.'s score*	*Control subjects' score*
Repetition[a]	18/18	18/18
Words	15/15	15/15
Syllables	6/6	6/6
Nonwords	3/3	3/3
Short sentences	3/3	3/3
Long sentences	1/1	3/3
Reading aloud		
Letters[a]	10/10	10/10
Short words[a]	4/6	6/6
Long words[a]	3/6	6/6
Words vs. nonwords[a]	10/10 vs. 10/10	10/10 vs. 10/10
Content vs. function words[a]	9/10 vs. 9/10	10/10 vs. 10/10
Regular vs. irregular words[b]	20/20 vs. 15/20	n.a.
Spelling[a]		
Letters	8/8	8/8
Words	7/12	n.a.
Nonwords	4/4	n.a.
Sentences	0/4	n.a.
Sentence-to-picture matching[a]		
Spoken sentences	10/16	n.a.
Auditory Lexical Decision	143/144	n.a.
Visual Lexical Decision	229/240	n.a.
Spoken Picture Naming[a,c]	9/35	n.a.
Spoken-word/Picture matching[d]	41/80	79.3 (SD = 0.46)
Pyramid and Palm Trees Test (Objects)[e]		
Pictures	17/52	51.25/52
Words	24/52	51.50/52
Kissing and Dancing Test (Actions)[f]		
Pictures	38/52	51.25/52
Words	48/52	51.50/52

Note: From examinations carried out in September 2004. n.a. = not available.
[a]Batterie d'Évaluation du Langage (Cliniques universitaires Saint-Luc, Brussels). [b]Crowet (2005). [c]The naming task includes 45 items but G.C. asked to stop the task after 35 items. [d]Lexis (de Partz, Bilocq, De Wilde, Seron, & Pillon, 2001). [e]French translation of the Pyramids and Palm Trees Test (Howard & Patterson, 1992), see d'Honincthun and Pillon (2008) for further details. [f]French translation of the Kissing and Dancing Test (Bak & Hodges, 2003), see d'Honincthun and Pillon (2008) for further details.

1992) for the object items and the "Kissing and Dancing Test" (KDT, Bak & Hodges, 2003) for the action items. G.C.'s performance in this task was impaired for both objects and actions, in both the picture and the written word versions. However, his performance was poorer for objects than for actions in both versions ($\chi^2 = 17.02$ and $\chi^2 = 26.00$ in the picture and the written version, respectively; both ps $< .0001$). Understanding the source of this dissociation between objects and actions has motivated the experimental study presented below.

EXPERIMENTAL STUDY

The experimental investigations were carried out from September 2004 to October 2006 in several sessions of 60 to 120 minutes.

Unless otherwise stated, all the tasks presented to G.C. were also presented to a control group comprising either 5 healthy right-handed participants closely matched to the patient for age (mean age = 43.2 years; range = 40–46) and education (mean number of years = 16.4; range = 15–17) or only 3 out of these 5 participants, also matched to the patient for age (mean age = 42.5 years; range = 40–44) and education (mean number of years = 16.3; range = 15–17). Because this subgroup of 3 participants was involved in the pantomime recognition and production tasks, their right-handedness, like the patient's, was checked with the Edinburgh Handedness Questionnaire (Oldfield, 1971).

Crawford and Howell's (1998) modified t test was used for testing whether the patient's performance for the various categories of probed items was significantly impaired in comparison to the control group's performance (test for the presence of a deficit), and Crawford and Garthwaite's (2007) Bayesian Standardized Difference Test (BSDT) was applied for testing whether the discrepancy between two item categories in the patient's performance was significantly different from the discrepancy observed in the performance of the control group (test for the presence of a dissociation). We used BSDT rather than the Revised Standardized

Difference test (RSDT, Crawford & Garthwaite, 2005) because BSDT provides a better protection against Type I error when the size of the control sample is small and, especially, when the patient's scores are extreme (z score < -3.0), which was the case in G.C. When these statistics could not be computed (e.g., because of the SD being nil in the controls' scores), we used the classical chi-square test to assess the difference in performance between two categories of items.

Naming and comprehension of objects, living things, artifacts, and actions

The "Objects/Actions" Battery

Conceptual knowledge for objects and actions was assessed in G.C. with the "Objects/Actions" Battery, which comprised an oral picture naming and a spoken-word–picture verification task both composed of the same set of object and action items pictured in colour photographs and an additional action naming task with the same set of action items pictured in videotapes. Furthermore, presemantic levels of processing involved in these tasks—that is, auditory word recognition and visual processing of photographs and videos—were assessed in a number of tasks, most of which used the items of this Objects/Actions Battery.

The Objects/Actions Battery comprised 72 items—namely, 36 objects (nouns) and 36 actions (verbs). The object set included 18 living things (9 animals and 9 fruit/vegetables) and 18 artifacts (9 tools/utensils and 9 artifacts from other categories like furniture, clothing, and vehicles). The action set included 18 object-directed actions (9 actions performed with a tool/instrument, e.g., "measuring", and 9 actions performed without a tool/instrument, e.g., "tearing up") and 18 "person-directed" actions (9 bodily actions, e.g., "stretching", and 9 actions involving two human beings, e.g., "whispering"). The object and the action item sets as well as the four item subsets (18 living things, 18 artifacts, 18 object-directed actions, 18 person-directed actions) were matched for objective and subjective name frequency as well as concept familiarity (see values in Table 3; pairwise t tests: $0.18 < t < 1.69$; $.10 < p < .99$).

Table 3. *Mean objective and mean subjective name frequency as well as mean concept familiarity of the items of the Objects/Actions Battery*

Category of Items	*Objective frequency*[a]	*Subjective frequency*[b]	*Concept familiarity*[c]
Living things	3.13	2.92	2.89
Artifacts	2.95	3.03	3.16
Total objects	3.04	2.98	3.02
Person-directed actions	3.27	3.10	3.17
Object-directed actions	3.28	3.12	3.13
Total actions	3.28	3.11	3.15

Note: [a]Log_{10} of printed frequency per 100 million occurrences (Content, Mousty, & Radeau, 1990). [b]Rated on a 5-point scale (1 = low frequency; 5 = high frequency) by 25 subjects for half of the items and 29 subjects for the second half (mean age of the 54 subjects = 66 years, $SD = 8.9$). [c]Rated on a 5-point scale (1 = low familiarity; 5 = high familiarity) by 27 subjects for half of the items and 26 subjects for the second half (mean age of the 53 subjects = 67 years, $SD = 9.7$).

Moreover, the four subsets of 9 items within the object set (animals, fruit/vegetables, tools/utensils, other artifacts) and the four subsets of 9 items within the action set (9 object-directed actions performed with a tool/instrument, 9 object-directed actions performed without a tool, 9 bodily actions, and 9 actions between two human beings) were matched for objective name frequency, concept familiarity, and, also, imageability.

A colour photograph picturing each object and action with no or a minimal context was selected. Most of the photographs of actions were drawn from Fiez and Tranel (1997). Three additional photographs per item were selected as foils for the word–picture verification task: one corresponding to a "close" semantic coordinate of the item, one to a "far" semantic coordinate of the item, and one that was semantically unrelated to the item. Videotapes corresponding to each photograph of actions were also prepared, so that the visual appearance of the action resembles as closely as possible the way it was depicted on the photograph. One action ("spinning") could not be filmed. The video naming task thus included 35 out of the 36 actions from the initial set. With the exception of movement and duration, the videotapes contained no additional information about the action in comparison to the static pictures.

Assessment of presemantic processing

- *Spoken word recognition*. G.C. was presented an auditory lexical decision task with the 36 nouns and 36 verbs of the Objects/Actions Battery and 72 nonwords made up by changing one or two phonemes in onset, middle, or rime position in these nouns and verbs. G.C. was asked to tell, for each auditory stimulus, whether it was a real French word or not. The patient scored at ceiling in this task (143/144 correct responses; the error consisted in accepting a nonword).
- *Visual processing of photographs of objects and actions*. Half of the 36 photographs of objects (half living, half nonliving) and half of the 36 photographs of actions (half object-directed, half person-directed) from the Objects/Actions Battery were presented one at a time to G.C. who was asked to reproduce by drawing each photograph so that the drawing resembled as much as possible the photograph. The patient was given a fresh sheet of paper for each photograph and an unlimited time to draw each still-in-sight item. The drawings produced by G.C. were scored 1 point if they represented accurately each of the elements present in the photograph. Figure 2 shows some examples of G.C.'s drawings that were scored correct or incorrect. In this task, the patient scored 15/18 for the photographs of objects (two errors on animal items and one error on an artifact item) and 16/18 for the photographs of actions (two errors on object-directed actions). His few errors consisted in not drawing small details of objects (e.g., not drawing completely the cat's whiskers or the fringes of the carpet) or part of the hands involved in actions (e.g., missing wrist); in every drawing, however, the object or the action was easily recognizable (see Figure 2).
- *Visual processing of the posture in the photographs of actions*. The 18 photographs of actions used in the drawing task were presented to G.C. in a posture imitation task. The patient was asked to imitate as precisely as possible the static posture of the individual performing the action in the (still-in-sight) photograph. He was instructed that his posture should be frozen just as it was in the photograph and that he should not perform the pictured action as he would in real life. The patient's responses were videotaped for subsequent scoring and were scored 1 point if they were identical to the posture depicted in the photographs. G.C. had a score of 16/18. Here, his errors were omitting to reproduce the posture of the legs in the action of pushing back someone and a lack of amplitude in lifting a leg in reproducing the action of dancing.
- *Visual processing of dynamic actions*. G.C. and the subgroup of 3 control subjects were presented with the 35 videotapes of actions and were asked to imitate the displayed actions as they would really perform them in real life—that is, as if they really held the object and/or the instrument when the action was performed on an object or as if they really were in the presence of another human being if the action involved two persons.

  The responses were videotaped for subsequent scoring, which followed Peigneux and Van der Linden's (2000) scheme of analysis (adapted from Rothi, Raymer, & Heilman, 1997). The scheme differentiated 16 error types belonging to four main categories—that is, content, temporal, spatial, and other errors. Content errors correspond to inappropriate but correctly performed pantomimes, temporal errors to disturbances of the action dynamics, and spatial errors to any disturbance in the amplitude or positioning of the digits, hand, or arm in space; other errors were hesitations, nonresponses, unrecognizable errors, and concretizations.[4]

[4]Peigneux and Van der Linden's (2000) scheme of analysis strictly follows Rothi et al.'s (1997) except for two adaptations. First, among the spatial errors, Rothi et al. identified the errors of internal and external configuration—namely, errors of finger/hand/arm posture in respect to a tool or to the object receiving the action. These two types of error, which applied specifically to pantomimes of object use (transitive gestures), were replaced by errors of digital versus manual configuration, respectively, which enabled use of the same spatial criteria for assessing meaningless and meaningful gestures and transitive and intransitive gestures. Second, an additional type of "other errors" was identified—that is, "initiation/hesitation", which designates an abnormally long pause or hesitations before producing the gesture, be it correct or not.

G.C. and the control subjects scored 57% correct (20/35) and 68% correct (23.6/35, range = 21−27, $SD = 8.62$), respectively. G.C.'s performance was not significantly impaired in comparison with that of the controls, $t(2) = -0.37$, $p > .70$. Moreover, the distribution of his errors was highly similar to that of the controls: From his total errors, 25% were temporal, and 75% were spatial errors, while, in the controls, 24% were temporal, and 76% were spatial errors. This pattern indicated that the visual processing of dynamic actions (and also the motor programming and execution of motion and gestures associated with our set of actions) was spared in the patient.

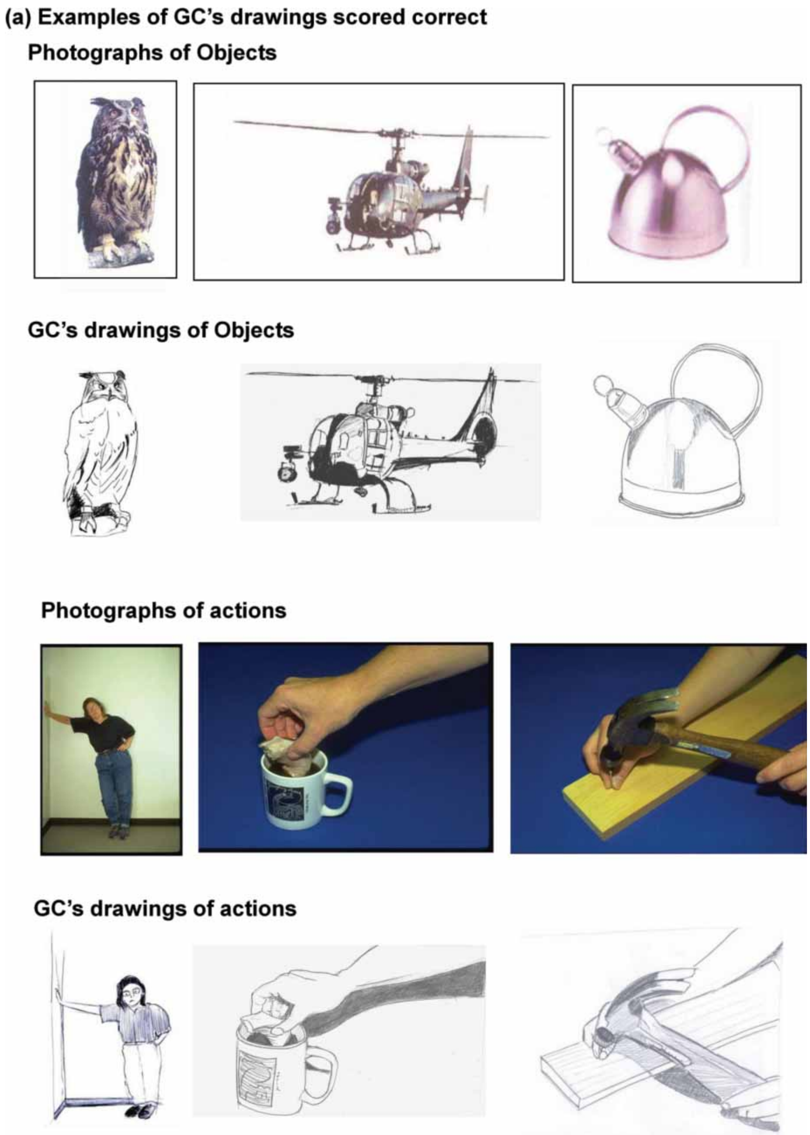

Figure 2. *Examples of G.C.'s drawings from photographs that were scored (a) correct and (b) incorrect. To view a colour version of this figure, please see the online issue of the Journal.*

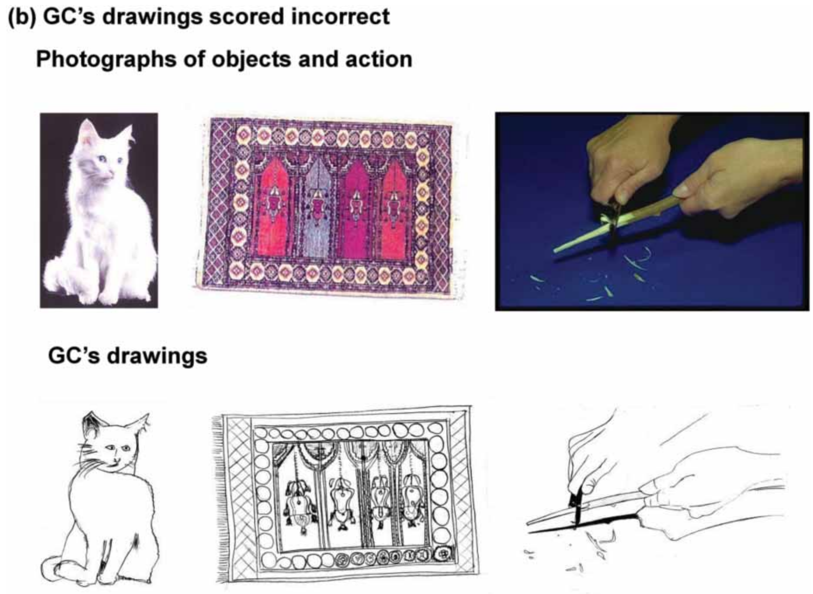

Figure 2. *Continued*

- *Visual recognition of gestures*. G.C. and the subgroup of 3 control subjects were presented a videotaped demonstration of 30 meaningful and 30 matched meaningless upper limb unimanual and bimanual gestures (Peigneux et al., 2001) and were asked to identify which were the meaningful gestures. The meaningful gestures included both object manipulations and communicative gestures. G.C. scored 57/60, which was within the range of the controls' scores (mean = 57/60; range = 56–58, $SD = 1$).

Picture naming and word–picture verification tasks

Procedure

In the picture naming task, G.C. and the group of 5 control subjects were asked to provide the spoken name of the object or the action depicted in the 72 photographs. At every object trial, the examiner prompted the participant's response with the question "What is this" and, at every action trial, with the question "What is s/he doing?". In the video naming task, the examiner also prompted the patient's response with the question "What is s/he doing?" at every trial. In the word–picture verification task, each item was presented as a spoken word, once with the correct photograph, once with the "close" semantic foil, once with the "far" semantic foil, and once with the unrelated foil. The participants were asked to tell whether the word was the correct name for the object or the action depicted in the photograph. An item was scored as correct when the participant both accepted the correct picture and rejected the three foils. These tasks were presented in several sessions, and the action and object items were alternated with an ABBA design.

Results

G.C.'s and the controls' scores, as well as the results of the test for the presence of a deficit (modified t test of Crawford & Howell, 1998) for each category of items are displayed in Table 4.

- *Objects versus actions*. G.C.'s performance in picture naming was significantly impaired for both objects and actions but tended to be more impaired for objects than actions (BSDT: $p = .08$). The patient's performance in naming actions did not improve when probed from videotapes (8/35) compared to static pictures

Table 4. *G.C.'s and control subjects' number and percentage of correct responses in the picture naming and the word–picture verification tasks of the Objects/Actions Battery*

	G.C.		Control subjects				
Task	N	%	*Mean*	%	SD	*Range*	*Modified* t *test*
Naming							
Living things	3/18	17	18.0/18	100	0.00	18–18	—[a]
Artifacts	6/18	33	17.6/18	98	0.55	17–18	$t(4) = -19.33, p < .0001$
Total objects	9/36	25	35.6/36	99	0.55	35–36	$t(4) = -44.33, p < .0001$
Person-directed actions	6/18	33	16.8/18	94	0.48	16–17	$t(4) = -20.66, p < .0001$
Object-directed actions	5/18	28	17.0/18	94	1.00	16–18	$t(4) = -10.95, p < .001$
Total actions	11/36	31	33.8/36	94	1.09	33–35	$t(4) = -19.00, p < .0001$
Word–picture verification							
Living things	0/18	0	18.0/18	100	0.00	18–18	—[a]
Artifacts	10/18	55	18.0/18	100	0.00	18–18	—[a]
Total objects	10/36	28	36.0/36	100	0.00	36–36	—[a]
Person-directed actions	9/18	50	17.4/18	97	0.55	17–18	$t(4) = -14.00, p < .0001$
Object-directed actions	11/18	61	17.0/18	94	0.71	16–18	$t(4) = -7.75, p < .001$
Total actions	20/36	55	34.4/36	95	0.55	34–35	$t(4) = -23.90, p < .0001$

Note: [a]Crawford and Howell's (1998) modified t test could not be applied because controls' standard deviation was nil.

of actions (9/35; $\chi^2 < 1$), and his naming errors (semantic paraphasias, circumlocutions, and nonresponses) presented a similar distribution in both conditions ($\chi^2 < 1$). In the word–picture verification task, G.C.'s performance was impaired for both objects and actions and, again, significantly more impaired for objects than for actions ($\chi^2 = 5.71, p < .02$).

- *Living things versus artifacts*. Within the object set, G.C.'s performance was impaired for both living things and artifacts, but it was poorer for living things than artifacts in both the naming and the word–picture verification task, although this difference reached significance in the verification task only ($\chi^2 = 13.84, p < .0001$).
- *Living things versus artifacts versus actions*. Given G.C.'s disproportionate impairment for living things compared to artifacts within the object set, we tested whether living things and artifacts were each differently impaired compared to actions. The results indicated that, in both the naming and the word–picture verification task, G.C.'s performance for living things was disproportionately impaired compared to both artifacts and actions, although this difference reached significance in the verification task only (living things vs. artifacts, $\chi^2 = 13.84, p < .001$; living things vs. actions, $\chi^2 = 15.88, p < .0001$). However, his performance for artifacts did not significantly differ from his performance for actions (in naming, BSDT: $p > .95$; in verification, $\chi^2 = 0$), although it was significantly impaired for both artifacts and actions in both naming and verification.
- *Living things versus artifacts versus object-directed actions versus person-directed actions*. Within the action set, G.C.'s performance for both object-directed and person-directed actions was significantly impaired in comparison to controls, in both the naming and the verification task, and his performance for both kinds of actions did not show a significantly different degree of impairment in naming (BSDT: $p > .20$) or verification (BSDT: $p > .15$). Moreover, and importantly, in both tasks, living things were more impaired than both object-directed and person-directed actions, although the difference reached significance in the verification task only (living things vs. object-directed actions;

$\chi^2 = 15.84$, $p < .001$; living things vs. person-directed actions: $\chi^2 = 12$, $p < .001$). In contrast, artifacts did not show a significantly different degree of impairment compared to both object-directed (naming: BSDT, $p > .05$; verification: $\chi^2 = 0.11$, $p > .70$) and person-directed actions (naming: BSDT, $p > .80$; verification: $\chi^2 = 0.11$, $p > .70$). Thus, the pattern of a disproportionate deficit for living things compared to both artifacts and actions holds whatever the kind of action considered and, in particular, whether the action involved the interaction with an object (artifact) or not.

- *Error distribution.* G.C.'s naming errors consisted in circumlocutions (60% of total errors), semantic paraphasias (35%), and nonresponses (5%). The distribution of these different kinds of errors was not significantly different across the four subcategories of items (living things, artifacts, and person-directed and object-directed actions: $\chi^2 = 2.76$; $p > .80$). In the word–picture verification task, G.C.'s errors consisted mainly in accepting the "close" semantic foil (41% of total errors), then in accepting the "far" semantic foil (32%) or rejecting the correct photograph (25%); very few errors thus consisted in accepting the unrelated foil (2%). The distribution of the different kinds of error was not significantly different across the four subcategories of items (living things, artifacts, and person-directed and object-directed actions: $\chi^2 = 10.23$; $p > .30$).

The "Living/Nonliving" Battery

In order to ascertain the reliability of the dissociation between living things and artifacts in G.C.'s performance with a different and larger set of items, he was presented with the 36 living thing (18 animals, 18 fruit/vegetables) and 36 nonliving thing (18 implements and 18 means of transport) items from the "Living/Nonliving" Battery (Samson et al., 1998) in an oral picture naming, an oral naming to verbal description, and a spoken-word–picture verification task. Only 8 (2 living and 6 nonliving) items out of the 72 items of this battery were also present in the object set of the Objects/Actions Battery. Moreover, in this battery, the items were depicted in black-and-white drawings instead of photographs. The living and nonliving things were matched for name frequency, concept familiarity, and visual complexity (see for details, Samson et al., 1998).

The control data for these tasks were those from Samson et al.'s (1998) study. Because the raw control data were not available, we did not compute the modified *t* test nor the BSDT and used the chi-square to test for potential differences in G.C.'s performance between item categories. The results (Table 5) indicated that G.C.'s performance in the three tasks was far below the control subjects' performance for both living and nonliving things and that, in the three tasks, his performance was significantly poorer for living than for nonliving things ($4 < \chi^2 < 6.4$; $.01 < p < .05$), which confirmed the pattern of a disproportionate deficit in naming and comprehending living things compared to artifacts found with the items of the Objects/Actions Battery.

Discussion

The results presented thus far indicated that G.C.'s naming and comprehension of concrete objects and actions were impaired but not to a similar degree for all semantic categories of items. Among the concrete objects, G.C. presented a disproportionate deficit for living things compared to artifacts. However, among the concrete actions, there was no evidence of a differential impairment for object-directed versus person-directed actions. Furthermore, there was no evidence of a differential impairment between the categories of actions and artifacts. The general pattern of G.C.'s impairment in naming and comprehension was thus of a disproportionate deficit for living things compared to artifacts and actions, which were similarly impaired.

G.C.'s performance across the various tasks assessing presemantic and semantic processing pointed to the conceptual level of processing as the locus of impairment for all categories of items. However, because the patient's naming performance for all categories was poorer than his performance in the verification task, which was nevertheless

Table 5. *G.C.'s and control subjects' number and percentage of correct responses in the three tasks of the Living/Nonliving Battery*

	G.C.		Control subjects		
Task	N	%	*Mean*	%	*Range*
Picture naming					
Living things	3/36	8	32.50/36	90	28–36
Artifacts	10/36	28	30.50/36	85	27–33
Naming to description					
Living things	2/36	6	28.50/36	79	27–34
Artifacts	10/36	28	29.25/36	81	27–30
Word–picture verification					
Living things	8/36	22	33.25/36	92	30–35
Artifacts	16/36	44	31.50/36	88	28–34

also a demanding semantic task (Breese & Hillis, 2004), it is likely that G.C. had an additional impairment at the word retrieval processing level. His near-floor performance in naming probably could explain why the pattern of significant differences between item categories observed in comprehension was less apparent in naming. Moreover, at this step, one cannot rule out that G.C.'s disproportionate deficit for living things compared to artifacts in the picture naming and the word–picture verification task with both batteries of items (Objects/Actions and Living/Nonliving) was partly due to a category-specific deficit located at the structural level of processing since, as indicated by his performance in the object decision tasks (see Case Report), G.C.'s visuostructural processing was more impaired for living things than for artifact items. However, G.C. presented the same pattern of a disproportionate deficit for living things compared to artifacts in a naming from a definition task (Living/Nonliving Battery), and his overall performance was not better in this task than in the picture naming task with the same items.

As regards the two less impaired categories, artifacts and actions, G.C.'s performance in the presemantic processing tasks allowed us to rule out visual processing difficulties, either visuostructural difficulties in processing pictures of artifacts (see also Case Report) or difficulties in processing the posture, gesture, or motion in photographs and videos of actions, as the source of the naming and comprehension impairment. In comprehension at least, G.C.'s deficit for artifacts and actions was thus probably located at the level of the conceptual representations of artifacts and actions.

In the next section, we provide additional evidence in support of the hypothesis that the locus of both the disproportionate impairment for living things compared to artifacts and the similar level of impairment for artifacts and actions was the conceptual level of processing, by showing that G.C. presented just the same pattern of deficit when his conceptual knowledge was assessed with a verbally presented property verification task—hence, with a task not requiring the processing of visual stimuli. The second and main aim of the experiments presented in the next section was to test whether the pattern of G.C.'s category-specific conceptual deficit could be accounted for by damage impairing one specific type of conceptual knowledge—say, sensory knowledge.

Assessing the "sensory/functional" account for G.C.'s pattern of conceptual impairment

According to a variant of the feature-based account for category-specific conceptual deficits, the "sensory/functional" account put forward by Bird et al. (2000), a disproportionate deficit for living things compared to both artifacts and actions would result in fact from a selective or disproportionate impairment of sensory compared to functional conceptual knowledge. Because, according to Bird et al. (2000), the ratio of sensory to functional features would be higher in the conceptual representations of living things than in the conceptual representations of both artifacts and actions, damage to sensory knowledge should impair the concepts of living things more than the concepts of artifacts and actions. Actually, on this view, the concepts of artifacts should show an intermediate level of impairment, because their ratio of sensory-to-functional features is thought to be intermediate between that of the concepts of living things and actions. G.C.'s pattern of conceptual impairment was not consistent with this prediction, since he was similarly impaired for artifacts and actions, but one may argue that this could be due to the particular items selected within the artifact set being more weighted for functional/motor features than are artifacts in general—we address this objection in the next section.

In any case, the "sensory/functional" account for category-specific conceptual deficits suggested by Bird et al. (2000) is committed to the prediction that a disproportionate deficit for living things should be associated with a disproportionate deficit for sensory knowledge compared to functional knowledge, a prediction that we tested in two property verification tasks, one created with the items of the Objects/Actions Battery and the second composed of the items of the Living/Nonliving Battery.

The various types of conceptual knowledge, and especially "functional" knowledge, have been characterized in different ways across studies (e.g., Caramazza & Shelton, 1998; Cree & McRae, 2003; Farah & McLelland, 1991; Garrard et al., 2001; McRae, de Sa, & Seidenberg, 1997; see, for discussion, Pillon & Samson, 2001). In preparing the statements of the property verification task, we attempted to follow as closely as possible Bird and colleagues' (2000) conception of the "sensory/functional" dichotomy, which, at least as regards the features of objects, was quite explicitly stated in their paper. In particular, the "functional" properties of objects had to be understood in the broader sense of "nonsensory" information, encompassing both function and use and associative and encyclopaedic knowledge. However, the authors did not specify how the term "functional" properties had to be understood in the case of the concepts of actions. In the property verification task, we considered as functional properties of actions those referring to their cause or purpose, which we believe fit the general meaning of "nonsensory" information—that is, information that cannot be derived from the senses.

However, in their paper, the authors sometimes referred to "motor" instead of "functional" features as the primary features of actions (and also of a subset of artifacts, i.e., tools). Because of this ambiguity and also because other authors within the FBO framework emphasized "action-related" or "motor" knowledge rather than "functional" knowledge as central for artifacts (at least, tools) and actions (e.g., Allport, 1985; Boronat et al., 2005; Buxbaum & Saffran, 1998; Gainotti, 1998, 2000; Humphreys & Forde, 2001), we further assessed the patient's knowledge of motor features for the action concepts of the Objects/Actions Battery by means of a pantomime task. (We did not assess motor knowledge of the artifact items included in this battery because not all of them were associated with a specific motor schemata.)

Probing sensory and functional knowledge related to living things, artifacts, and actions in two property verification tasks

Method

Each of the 72 items of the Objects/Actions Battery was used as a spoken name in four verbal statements, two stating sensory properties (one true and one false) and two stating functional properties (one true and one false) of the object or the action. False statements were constructed by assigning to a given item a true property of its close semantic foil used in the word–picture verification task. G.C. and the group of 5 control subjects were auditorily presented with each statement and were asked to tell whether it was true or false. Following Bird and colleagues' (2000) conception of functional knowledge, the functional properties of objects referred to eating habits or living environment for animals, growing environment or modes of cooking for fruit and vegetables, functional use for implements, and, for means of transport, what is transported or the specific place where it is used. As for the sensory properties, we considered mainly visual properties of objects—that is, the shape, parts, colour or material of the object—but not exclusively (e.g., taste for fruit or feel for plants). The statements probing the functional properties of an action referred to its cause, goal, purpose, or consequence, and those probing the sensory properties of an action described the visual appearance of the motion that is typical of the action (see examples of sensory and functional statements for objects and actions in the Appendix).

In order to further assess G.C.'s sensory and functional knowledge for living things and artifacts with a different and larger set of items, we also presented him with the property verification task of Samson et al. (1998), which included the items of the Living/Nonliving Battery. Each of the 72 items (36 living things and 36 nonliving things, i.e., artifacts) appeared in four verbal statements—that is, two describing a sensory property (one true, one false) and two describing a functional property (one true, one false). False statements were constructed by assigning a true property of an item to another item of the same category. Here, the sensory properties were in fact only visual properties, and the functional properties encompassed the same kinds of properties as in the verification task with the items of the Objects/Actions Battery. The average difficulty of the verbal statements, rated on a 5-point scale by 5 well-educated young adults (Samson et al., 1998), did not significantly differ between living and nonliving items or between the visual and the functional statements, both $Fs(1, 280) < 1$. G.C. was presented all the statements ($n = 288$) simultaneously in written and spoken form, in two sessions (half of the sensory and half of the functional statements in each session) and was asked to tell whether each statement was true or not. For this task, the control data were those from Samson et al.'s (1998) study. Because the raw control data were not available, we did not compute the modified t test or the BSDT and used the chi-square to test for potential differences in G.C.'s performance between semantic categories and properties.

Results

We first considered G.C.'s overall performance in both property verification tasks (that with the Objects/Actions items and that with the Living/Nonliving items) by scoring an item as correct when, for this item, both the sensory and the functional true statements were accepted, and both the sensory and the functional false statements were rejected. The results for the Objects/Actions items are displayed in Table 6. They indicated that G.C.'s performance in this task was significantly impaired for both objects and actions and that he was significantly more impaired for objects than for actions (BSDT: $p < .05$). Within the object set, his performance was significantly impaired both for living things and for artifacts and tended to be more impaired for living things than for artifacts (BSDT: $p = .06$). In fact, there was a trend for G.C.'s performance being more impaired for living things than for both artifacts (BSDT: $p = .06$) and actions (BSDT: $p = .09$), which were both similarly impaired (BSDT: $p > .40$). Within the action set, both object- and person-directed actions were significantly impaired, and there was no evidence that these kinds of actions dissociated (BSDT: $p > .40$). Furthermore, living things were significantly more impaired than both object-directed (BSDT: $p < .01$) and person-directed actions (BSDT: $p = .05$), whereas artifacts were not differentially impaired compared to object-directed (BSDT: $p > .60$) or person-directed (BSDT: $p > .70$) actions. In the property verification task with the Living/Nonliving items, G.C.'s scores were 1/36 for living things and 17/36 for artifacts, which indicated, once again, that G.C.'s knowledge was significantly poorer for living things than for artifacts ($\chi^2 = 18.96$, $p < .001$).

We then considered separately the statements probing sensory and functional properties and scored an item as correct when both the true statement was accepted, and the false one was rejected. The results for the Objects/Actions items, displayed in Table 7, indicated that the patient's performance was significantly impaired for both sensory and functional properties, and there was no evidence for a dissociation between these

Table 6. *G.C.'s and control subjects' number and percentage of correct responses in the property verification task for the items of the Objects/Actions Battery*

	G.C.		Control subjects				
Category of items	N	%	*Mean*	%	SD	*Range*	*Modified* t *test*
Living things	0/18	0	16.0/18	89	0.71	15–17	$t(4) = -20.66, p < .0001$
Artifacts	8/18	44	15.2/18	84	0.84	14–16	$t(4) = -7.86, p < .001$
Total objects	8/36	22	31.2/36	87	1.09	30–33	$t(4) = -19.34, p < .0001$
Person-directed actions	9/18	50	14.6/18	81	0.55	14–15	$t(4) = -9.33, p < .001$
Object-directed actions	4/18	22	14.6/18	81	1.52	12–16	$t(4) = -6.38, p < .01$
Total actions	13/36	36	29.2/36	81	1.30	27–30	$t(4) = -11.34, p < .001$

types of properties (BSDT: $p > 0.30$). The same pattern was found within each category of items. Thus, in each category or subcategory of items (objects, actions, living things, artifacts, object-directed actions, and person-directed actions), G.C.'s performance was significantly impaired for both the sensory and the functional properties of items but in none of these categories or subcategories was he significantly more impaired for the sensory than for the functional properties (BSDT: $.13 < p < .80$).

G.C.'s performance with the Living/Nonliving items showed the same pattern (see Table 8). Thus, the patient's performance was below the controls' range for both sensory and functional properties of both living things and artifacts. However, neither in the living nor in the artifact category was his performance significantly different for the sensory and the functional properties (both $\chi^2 < 1$). Moreover, no significant difference between sensory and functional properties emerged

Table 7. *G.C.'s and control subjects' number and percentage of correct responses for the items of the Objects/Actions Battery in the property verification task and according to the type of property probed*

	G.C.		Control subjects				
Type of property	N	%	*Mean*	%	SD	*Range*	*Modified* t *test*
Sensory properties							
Living things	3/18	17	17.2/18	95	0.84	16–18	$t(4) = -15.49, p < .0001$
Artifacts	10/18	55	17.2/18	95	0.84	16–18	$t(4) = -7.86, p < .001$
Total objects	13/36	36	34.4/36	95	1.52	32–35	$t(4) = -12.89, p < .001$
Person-directed actions	11/18	61	16.2/18	90	1.48	14–18	$t(4) = -3.20, p < .05$
Object-directed actions	9/18	50	16.8/18	93	0.45	16–17	$t(4) = -15.93, p < .0001$
Total actions	20/36	55	33.0/36	92	1.41	31–35	$t(4) = -8.39, p < .001$
Total sensory properties	33/72	46	67.4/72	94	1.82	65–70	$t(4) = -17.29, p < .0001$
Functional properties							
Living things	5/18	28	16.8/18	93	0.84	16–18	$t(4) = -12.88, p < .001$
Artifacts	11/18	61	15.6/18	87	0.55	15–16	$t(4) = -7.67, p < .001$
Total objects	16/36	44	32.4/36	90	0.89	31–33	$t(4) = -16.74, p < .0001$
Person-directed actions	13/18	72	15.2/18	84	0.84	14–16	$t(4) = -2.40, p < .05$
Object-directed actions	8/18	44	15.4/18	85	0.89	14–16	$t(4) = -7.55, p < .001$
Total actions	21/36	58	30.6/36	85	1.14	29–32	$t(4) = -7.68, p < .001$
Total functional properties	37/72	51	63.0/72	87	1.00	62–64	$t(4) = -23.73, p < .001$

Table 8. *G.C.'s and control subjects' number and percentage of correct responses for the items of the Living/Nonliving Battery in the property verification task and according to the type of property probed*

	G.C.		Control subjects		
Type of property	N	%	*Mean*	%	*Range*
Sensory properties					
Living things	4/36	11	27.25/36	75.7	23–30
Artifacts	21/36	58	27.25/36	75.7	25–31
Functional properties					
Living things	4/36	11	26.75/36	74.3	23–34
Artifacts	23/36	64	29.50/36	81.9	27–31

when the data for living things and artifacts were pooled ($\chi^2 < 1$).

Probing motor knowledge related to actions in a pantomime task

Method

G.C. and the subgroup of 3 control subjects were presented with the name and, in a separate session, the photograph of the 36 action items of the Actions/Objects Battery and were asked to pantomime the action "as they really did it in real life". The participants' responses were videotaped for subsequent scoring, which was based on Peigneux and Van der Linden's (2000) scheme.

Results

As displayed in Table 9, the patient was significantly impaired in pantomiming actions both from an action name and from an action photograph, and he was significantly impaired in pantomiming both person- and object-directed actions in both modalities of prompting. There was no evidence of a differential degree of impairment according to the modality of prompting (BSDT: $p > .60$) and no evidence of a differential degree of impairment in pantomiming person- versus object-directed actions from a name (BSDT: $p > .10$) or from a photograph (BSDT: $p > .70$).

Whereas the control subjects mostly made spatial errors in both modalities (69% and 78% of the total errors, in the name and the photograph condition, respectively), the distribution of the patient's errors slightly differed according to the modality: When pantomiming from a name, G.C. produced mostly content errors (53%) and then spatial (31%) and temporal (12%) errors, whilst from a photograph, he produced mostly spatial

Table 9. *G.C.'s and control subjects' number and percentage of correct responses in the pantomime task probing motor knowledge for the 36 actions of the Objects/Actions Battery and according to the modality of prompting*

	G.C.		Control subjects				
Modality of prompting	N	%	*Mean*	%	SD	*Range*	*Modified* t *test*
From the action name							
Person-directed actions	7/18	39	15.0/18	83	1.73	13–16	$t(2) = -4.00, p < .05$
Object-directed actions	2/18	11	10.7/18	59	0.58	10–11	$t(2) = -13.00, p < .01$
Total	9/36	25	25.7/36	71	1.53	24–27	$t(2) = -9.45, p < .01$
From the action photograph							
Person-directed actions	5/18	28	14.3/18	80	1.15	13–15	$t(2) = -7.00, p < .01$
Object-directed actions	3/18	17	10.3/18	57	1.15	9–11	$t(2) = -5.50, p < .05$
Total	8/36	22	24.7/36	68	1.15	24–26	$t(2) = -12.50, p < .01$

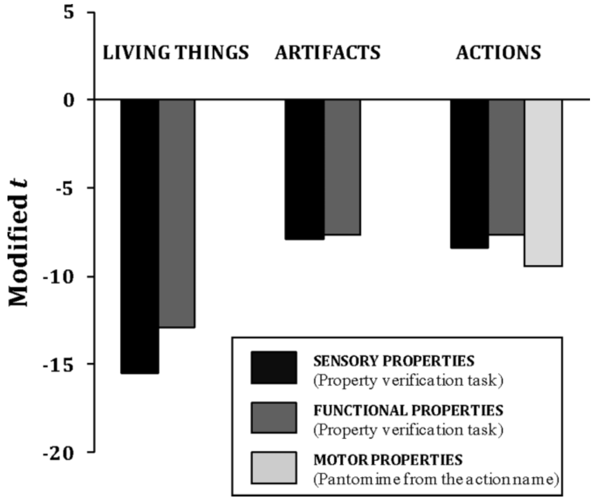

Figure 3. *Degree of G.C.'s impairment (expressed in modified* t*) in retrieving sensory, functional, and motor properties of the items of the Objects/Actions Battery.*

errors (41%) and then temporal (29%) and content (27%) errors (in both modalities, the remaining errors were "other errors", i.e., nonresponses or unrecognizable pantomimes). However, the distribution of the patient's errors did not significantly differ between both modalities ($\chi^2 = 6.08$; $p >$ .10). It did not significantly differ between person- and directed-actions either ($\chi^2 < 1$).

G.C. thus appeared to be impaired in retrieving motor knowledge associated with the concepts of actions, even when prompted with the photograph of the actions. The locus of this impairment cannot be in the programming, execution, or control of the movements and gestures associated with actions, since we showed that the patient's ability to perform the same actions on imitation was spared (cf. assessment of presemantic processing: visual recognition of dynamic actions). Hence, motor knowledge, like sensory and functional knowledge, was impaired in G.C. for actions. Moreover, as indicated by the modified t-values expressing the degree of impairment in retrieving these three types of knowledge probed from verbal input (see Figure 3), motor knowledge for actions was not less impaired than sensory or functional knowledge. In contrast, it turned out that all types of knowledge related to actions—sensory, functional, and motor—albeit impaired, were less impaired than all types of knowledge—sensory and functional—related to living things[5]—a pattern that is inconsistent with a "sensory–functional" or "sensory–motor" account for the disproportionate impairment for living things.

Discussion

G.C.'s overall performance in both the property verification tasks showed a pattern of impairment that strictly paralleled the pattern that was observed in naming and word–picture verification with the same sets of items—namely, a disproportionate impairment for living things compared to both artifacts and actions, which were similarly impaired. That G.C.'s

[5]It was not possible to compute BSDT to compare G.C.'s impairment for sensory versus motor knowledge of actions because the number of control subjects was different for the sensory and the motor knowledge probing task (the property verification task and the pantomime task, respectively). If only the 3 subjects having participated in both tasks were considered, BSDT could not be computed because the standard deviation in this subgroup was nil for the scores of the sensory features of actions. For the same reasons, it was not possible to compute BSDT to compare G.C.'s impairment for the various kinds of knowledge across actions and living things.

performance for living things was disproportionately impaired compared to artifacts in a task not requiring visuostructural processing confirmed that, beyond his category-specific visuostructural deficit for living things, the patient presented a disproportionate conceptual deficit for living things compared to artifacts and actions. Moreover, that G.C. showed, in this task, like in the naming and the word–picture verification task, the same level of impairment for the artifacts and the two categories of actions strengthened the hypothesis of the conceptual nature of the impairment for both artifacts and actions. Thus, the pattern of G.C.'s overall performance in the property verification tasks provided additional support to the hypothesis that the conceptual level of processing was indeed the locus of both the disproportionate impairment for living things compared to artifacts and the similar level of impairment for artifacts and actions.

G.C.'s disproportionate impairment for living things compared to both artifacts and actions could be accounted for with parsimony within Bird and colleagues' (2000) account for category-specific conceptual deficits, which needs only assume a disproportionate damage to the sensory compared to the functional knowledge system. However, the present evidence did not support this account, whatever the interpretation given to the term "functional"—that is, as encompassing nonsensory information like function, use, and associative knowledge or as referring to motor knowledge on how to perform an action. Contrary to the predictions made by the "sensory/functional" account, G.C.'s performance was not significantly more impaired for sensory than for functional or motor knowledge, on the whole and whatever the particular category of items—that is, living things, artifacts, and person- and object-directed actions, whereas both sensory and functional knowledge was disproportionately impaired for the concepts of living things in comparison with the concepts of artifacts and actions. In the next section, we present experiments aiming at testing an alternative FBO account for G.C.'s pattern of conceptual impairment.

Assessing the "manipulability" account for G.C.'s pattern of conceptual impairment

The results gathered thus far allowed us to reject the view according to which the conceptual representations of artifacts and actions were both less impaired than the conceptual representations of living things in G.C. because of their both relying more heavily on functional–motor knowledge compared to sensory knowledge. An alternative feature-based account for G.C.'s pattern of conceptual impairment should be considered, however. G.C.'s milder impairment for both the concept of artifacts and the concept of actions than for the concepts of living things could result from both categories relying heavily on a more specific type of sensorimotor knowledge, that is, manipulation knowledge, which would be relatively spared in G.C. (e.g., Gerlach et al., 2002; Kellenbach et al., 2003; Noppeney et al., 2005; Saccuman et al., 2006). Actually, most of the artifact (65%) and most of the action (69%) items from the Objects/Actions Battery could be characterized as manipulable artifacts or as actions with manipulation. The "manipulability" account predicts that the concepts that are weighted for manipulation features—that is, both artifacts and actions for which utilization or realization requires fine hand movements—would be less impaired than those that are not—that is, both artifacts and actions that do not involve hand movements. Furthermore, this pattern should be associated with a relative sparing of manipulation knowledge. The first of these predictions was tested in a picture naming and a word–picture verification task with artifact and action items that were weighted versus not weighted for manipulation features, and the second in a pantomime production task.

Picture naming and word–picture verification with manipulable and nonmanipulable items

Material

The "Manipulable/Nonmanipulable" Battery included 32 common artifacts and 32 common actions, half of which were "manipulable"—that is, entailed manipulation (e.g., "hammer" or "tickling")—and the other half did not (e.g., "bathtub" or "singing"). The 32 artifacts and 32 actions were matched for name frequency and concept familiarity, and the 32 manipulable and the 32 nonmanipulable items were matched for name frequency, concept familiarity, and imageability (see Table 10).

Following Saccuman et al. (2006), the representation of an artifact or an action was deemed to be associated with manipulation features if the utilization of the artifact or the realization of the action entailed specific and fine hand motion. Manipulability was estimated by three independent judges who were asked to tell whether 60 artifacts and 60 actions entailed manipulation according to the following instructions: "An object is manipulable if it is typically associated with a specific hand action involving either grasping the object to use it as a tool (e.g., a brush) or a manipulation of the object in order to achieve a result. Nonmanipulable objects are impossible to grasp and cannot be used as tools (e.g., a carpet). An action is considered a manipulation if it involves the grasping or other fine hand movements performed on an object (e.g., peeling). Nonmanipulation actions are performed either with the whole body moving through space (e.g., jumping) or with another body part than the hand (e.g., smiling)." Only items that reached 100% agreement across the judges were selected.

A colour photograph was chosen for representing each artifact and action with no or a minimal context. Most of the photographs of actions were drawn from Fiez and Tranel (1997). Two additional photographs per item were selected as foils for the word–picture verification task, one corresponding to a semantic coordinate of the item and one that was not semantically related to the item.

Procedure

In the picture naming task, G.C. and the group of 5 control subjects were asked to provide the spoken name of the artifact or the action depicted in the 64 photographs. At every object trial, the examiner prompted the participant's response with the question "What is this?" and, at every action trial, with the question "What is s/he doing?". Presentation of the action and artifact trials was alternated in an ABBA design applied through four sessions. In the word–picture

Table 10. *Mean name frequency, concept familiarity, and imageability for manipulable and nonmanipulable artifacts and actions*

	Name frequency[a]	*Concept familiarity*[b]	*Imageability*[c]
Manipulable items			
Artifacts	6.28	2.79	4.56
Actions	6.08	3.07	3.68
Nonmanipulable items			
Artifacts	6.37	3.02	4.62
Actions	6.25	3.34	3.83
Total manipulable items	6.18	2.93	4.12
Total nonmanipulable items	6.31	3.18	4.22
t test	0.83	1.15	0.65
p value	.41	.25	.51
Total artifacts	6.32	2.90	4.59
Total actions	6.16	3.20	3.75
t test	1.01	1.42	7.26
p value	.32	.16	<.001

Note: [a]Log_{10} of frequency per million of web pages from *Fastsearch* (New, Pallier, Brysbaert, & Ferrand, 2004). [b]Rated on a 5-point scale (1 = low familiarity; 5 = high familiarity) by 20 subjects (mean age = 35.95 years, *SD* = 11.01). [c]Rated on a 5-point scale (1 = low imageability; 5 = high imageability) by 20 subjects (mean age = 29.15 years, *SD* = 7.47).

Table 11. *G.C.'s and control subjects' number and percentage of correct responses for manipulable and nonmanipulable artifacts and actions in picture naming and word–picture verification*

	G.C.		Control subjects				
Task	N	%	*Mean*	%	SD	*Range*	*Modified* t *test*
Picture naming							
Manipulable							
Artifacts	4/16	25	15.6/16	97	0.55	15–16	$t(4) = -19.33, p < .0001$
Actions	4/16	25	15.4/16	96	0.55	15–16	$t(4) = -19.00, p < .0001$
Total	8/32	25	31.0/32	97	0.71	30–32	$t(4) = -29.70, p < .0001$
Nonmanipulable							
Artifacts	3/16	19	15.4/16	96	0.55	15–16	$t(4) = -20.69, p < .0001$
Actions	3/16	19	15.8/16	99	0.45	15–16	$t(4) = -26.13, p < .0001$
Total	6/32	19	31.2/32	97	0.45	30–32	$t(4) = -51.46, p < .0001$
Total artifacts	7/32	22	31.0/32	97	1.00	30–32	$t(4) = -21.91, p < .0001$
Total actions	7/32	22	31.0/32	97	0.00	31–31	—[a]
Word–picture verification							
Manipulable							
Artifacts	9/16	56	15.2/16	95	0.84	14–16	$t(4) = -6.76, p < .01$
Actions	10/16	62	15.0/16	94	0.71	14–16	$t(4) = -6.45, p < .01$
Total	19/32	59	30.2/32	94	0.84	28–32	$t(4) = -12.22, p < .001$
Nonmanipulable							
Artifacts	10/16	62	15.0/16	94	0.71	14–16	$t(4) = -6.46, p < .01$
Actions	9/16	56	15.8/16	99	0.45	15–16	$t(4) = -13.88, p < .0001$
Total	19/32	59	30.8/32	96	0.84	29–32	$t(4) = -12.87, p < .001$
Total artifacts	19/32	59	30.2/32	94	0.84	29–31	$t(4) = -12.22, p < .001$
Total actions	19/32	59	30.8/32	96	0.84	30–32	$t(4) = -12.87, p < .001$

Note: [a]Crawford and Howell's (1998) modified t test could not be applied in this case because controls' standard deviation was nil.

verification task, each item was presented as a spoken word, once with the correct photograph, once with the semantic foil, and once with the unrelated foil. The participants were asked to tell whether the word was the correct name for the object or the action depicted in the photograph. An item was scored correct when the participant both accepted the correct picture and rejected the two foils. The task was presented in several sessions, and the action and object items were alternated with an ABBA design.

Results and discussion

The results are displayed in Table 11. In the picture naming task, G.C. was impaired for both artifacts and actions, and he was as impaired for artifacts as for actions ($\chi^2 = 0$). The same pattern was found in the word-to-picture verification task, where G.C.'s performance was as impaired for artifacts as for actions (BSDT: $p > .90$). These results thus confirmed the pattern of similar impairment for artifacts and actions previously observed in a naming and a word–picture verification task with a different set of items (Objects/Actions Battery).

Examining the effect of manipulability in naming, the results showed that G.C.'s performance was impaired for both manipulable and nonmanipulable items, whether artifacts or actions, and as impaired for manipulable as for nonmanipulable items (BSDT: $p > .20$), whether artifacts (BSDT: $p > .80$) or actions (BSDT: $p > .40$). In the word–picture verification task, no significant effect of manipulability was detectable either. G.C.'s performance was significantly impaired for both manipulable and nonmanipulable items, whether artifacts or actions, and as impaired for manipulable as for nonmanipulable items (BSDT: $p > .90$), whether artifacts (BSDT: $p > .90$) or actions (BSDT: $p > .13$).

The results of these experiments first confirmed with a different set of items G.C.'s similar degree of naming and comprehension deficit for artifacts and actions. Second, they indicated that G.C.'s milder impairment for both the concepts of artifacts and the concepts of actions than for the concepts of living things could not be due to the conceptual representations of artifacts and actions heavily relying on manipulation knowledge: G.C.'s naming and comprehension of artifacts and actions was not influenced by the items being weighted or not for manipulation features. In the experiment presented next, we assessed the second prediction made by the manipulability account for G.C.'s pattern of conceptual impairment—that is, that it should be associated with a relative sparing of manipulation knowledge.

Assessing manipulation knowledge related to artifacts and actions

Material

In order to assess manipulation knowledge in G.C., the 16 manipulable artifacts and the 16 manipulation actions from the naming and the word–picture verification tasks were presented to him and the subgroup of 3 controls in a pantomime production task prompted either from the name or from the photograph of artifacts or actions. A pantomime imitation task with the same items was also presented to the participants, in order to assess the integrity of the motor programming and execution in G.C.

Procedure

In the pantomime imitation task, the participants were presented with videotaped pantomimes corresponding to the utilization of the 16 artifacts and the realization of the 16 actions and were asked to imitate these pantomimes. The participants were allowed to start imitation as soon as the videotape of a pantomime was terminated. In the pantomime production task, the participants were given the name and, in a separate session, the photograph of the artifacts and the actions and were instructed to perform the pantomime corresponding to the utilization of the artifacts or the realization of the actions. In both the imitation and the production task, the instructions to participants stressed the need for acting as in real life—that is, to perform the manipulation as if they really held the artifact or as if the other human being involved in the action (e.g., tickling) was present. Presentation of the action and artifact trials was alternated in an ABBA design in both the imitation and the production task. The responses produced in both tasks were videotaped for subsequent scoring, which, again, was based on Peigneux and Van der Linden's (2000) scheme.

Results and discussion

The results are displayed in Table 12. In the pantomime imitation task, in comparison to the controls, G.C.'s performance was spared for both artifacts and actions, which indicated that the visual processing of gestures and their motor programming and execution were spared in the patient. In contrast, his performance in producing pantomimes was significantly impaired for both artifacts and actions, when prompted by the name or the photograph, but there was no dissociation between artifacts and actions regardless of whether they were prompted by the name (BSDT: $p > .18$) or the photograph (BSDT: $p > .26$). Moreover, the error distribution did not significantly differ between artifacts and actions ($\chi^2 = 1.96$, $p > .50$). However, G.C.'s performance was significantly more impaired when prompted from the name than from the photograph (BSDT: $p < 0.001$), and the error distribution significantly differed between both conditions ($\chi^2 = 10.61$, $p < .02$). This difference mainly resulted from G.C.'s producing more "other errors" (i.e., nonresponses and unrecognizable pantomimes), in both absolute and relative number, in the verbal than in the photograph condition (see Table 13).

These results indicated that G.C. was impaired in retrieving manipulation knowledge both from the name of an artifact or an action and from their photograph, although the retrieval of manipulation knowledge was facilitated when prompted from a photograph. This facilitatory effect of the visual over the verbal presentation of the stimuli could reflect a "privileged access"

Table 12. *G.C.'s and control subjects' number and percentage of correct responses for artifacts and actions in the pantomime imitation task and the pantomime production tasks*

	G.C.		Control subjects				
Task	N	%	*Mean*	%	SD	*Range*	*Modified* t *test*
Pantomime imitation							
Artifacts	10/16	62	10.7	67	0.58	10–11	$t(2) = -1.00, p > .20$
Actions	13/16	81	12.3	77	1.15	11–13	$t(2) = 0.50, p > .30$
Total	23/32	72	23.0	72	1.73	21–24	$t(2) = 0$
Pantomime from name							
Artifacts	1/16	6	11.3	71	0.58	11–12	$t(2) = -15.51, p < .01$
Actions	3/16	19	12.3	78	1.15	11–13	$t(2) = -7.00, p < .01$
Total	4/32	12	23.7	74	1.53	22–25	$t(2) = -11.15, p < .01$
Pantomime from photo							
Artifacts	3/16	19	12	75	1.00	11–13	$t(2) = -7.79, p < .01$
Actions	6/16	37	13.7	85	0.58	13–14	$t(2) = -11.50, p < .01$
Total	9/32	28	25.7	80	1.53	24–27	$t(2) = -9.45, p < .01$

phenomenon by which specific sensory features present in the visual stimulus (e.g., the particular shape of the object or the posture of the arm/hand) could directly activate at least some manipulation features within long-term knowledge representations of objects or actions (e.g., Caramazza et al., 1990; Hillis & Caramazza, 1995; Rumiati & Humphreys, 1998). However, in spite of these facilitatory mechanisms, G.C.'s ability to retrieve manipulation knowledge from visual stimuli was impaired. Importantly, basing on the modified t-values (which reflect the severity of the patient's deficit) for the various types of knowledge assessed in this study, there was no evidence that manipulation knowledge was less impaired than either sensory, functional, or more general motor knowledge associated with artifacts or actions. Thus, the t-values for the deficit in retrieving the sensory properties of artifacts and actions were −7.86 and −8.39, respectively, and the t-values for the deficit in retrieving their functional properties were −7.67 and −7.68, respectively (see Table 7). As for the t-value for the deficit in retrieving the motor properties of actions when probed from photographs, it was −12.50 (Table 9), whilst the t-values for the deficit in retrieving the manipulation properties of artifacts and actions when probed from photographs were −7.79 and −11.50, respectively (Table 12). Thus, manipulation knowledge did not tend to be less impaired than the other types of semantic knowledge related to artifacts and actions. We appreciate that manipulation knowledge, on one hand, and sensory, functional, and motor knowledge, on the other hand, were probed with different sets of items—that is, the manipulable items of the Manipulable/Nonmanipulable Battery and the items of the Objects/Actions Battery, respectively; however, both sets of items gave rise to a very similar level of performance in the word–picture verification task (59% of correct responses for the manipulable items and 55% of correct responses for the items of the Objects/Actions Battery), which suggests that both sets of items probably presented a similar degree of difficulty for G.C. Thus, the second prediction made by the manipulability account for G.C.'s pattern of conceptual impairment—that is, that it should be associated with a relative sparing of manipulation knowledge—was not confirmed by the present results.

In sum, the findings of the two series of experiments presented in this section were at odds with both the predictions made by the "manipulability" account for G.C.'s pattern of conceptual impairment. G.C.'s milder impairment for both the concepts of artifacts and the concepts of actions than for the concepts of living things

Table 13. *G.C.'s and control subjects' distribution of errors in the pantomime imitation task and the pantomime production tasks*

	Artifacts G.C.		*Actions G.C.*		*Total G.C.*		*Total control subjects*		
Task	N	%	N	%	N	%	*Mean*	%	*Range*
Pantomime imitation									
Content errors	0	0	0	0	0	0	0.00	0	0–0
Temporal errors	1	20	0	0	1	12	2.00	22	1–3
Spatial errors	4	80	3	100	7	87	7.00	78	5–9
Other errors	0	0	0	0	0	0	0.00	0	0–0
Total	5	100	3	100	8	100	9.00	100	8–10
Pantomime from name									
Content errors	6	31	4	23	10	28	1.00	11	1–1
Temporal errors	2	10	3	18	5	14	1.33	15	1–2
Spatial errors	4	21	6	35	10	28	6.00	67	5–7
Other errors	7	37	4	23	11	30	0.66	7	0–1
Total	19	100	17	100	36	100	9.00	100	7–11
Pantomime from photo									
Content errors	4	23	3	21	7	22	0.67	8	0–2
Temporal errors	6	35	4	29	10	32	1.67	20	1–3
Spatial errors	6	35	7	50	13	42	5.66	72	5–7
Other errors	1	6	0	0	1	3	0.00	0	0–0
Total	17	100	14	100	31	100	8.00	100	6–10

could not be accounted for by the conceptual representations of artifacts and actions relying heavily on a specific type of sensorimotor knowledge, that is, manipulation knowledge, which would be relatively spared.

Additional analyses

To the best of our knowledge, the specific pattern of conceptual impairment presented by G.C. has not been reported yet in the neuropsychological literature. As shown in Figure 4, this specific pattern emerged consistently and reliably across the various experiments carried out in this study. With both the items of the Objects/Actions Battery and those of the Living/Nonliving Battery, we found evidence that G.C. was disproportionately impaired for living things compared to artifacts, in naming, word–picture verification, and property verification. The results of this study thus showed a pattern of a disproportionate deficit for living things that was consistent across both tasks and item sets. On the other hand, a similar level of impairment for artifacts and actions was consistently observed across tasks and item sets. Thus, no evidence for a differential impairment between artifacts and actions was found in G.C., neither with the items of the Objects/Actions Battery nor with those of the Manipulable/Nonmanipulable Battery and, again, in all the tasks requiring access to conceptual knowledge—that is, picture naming, word–picture verification, property verification, or pantomime production.

We showed that the similar degree of impairment for artifacts and actions could not be accounted for by their relying heavily on a common type of semantic properties that would be relatively spared, say, functional/motor or manipulation properties. Before considering alternative accounts for this association of deficits, however, one has to rule out that this finding, based on a null effect, was due to the small number of items in each set. To this end, we reanalysed the data from the word–picture verification and the naming task with the artifact and action items of both the Objects/Actions and the Manipulable/Nonmanipulable batteries, by

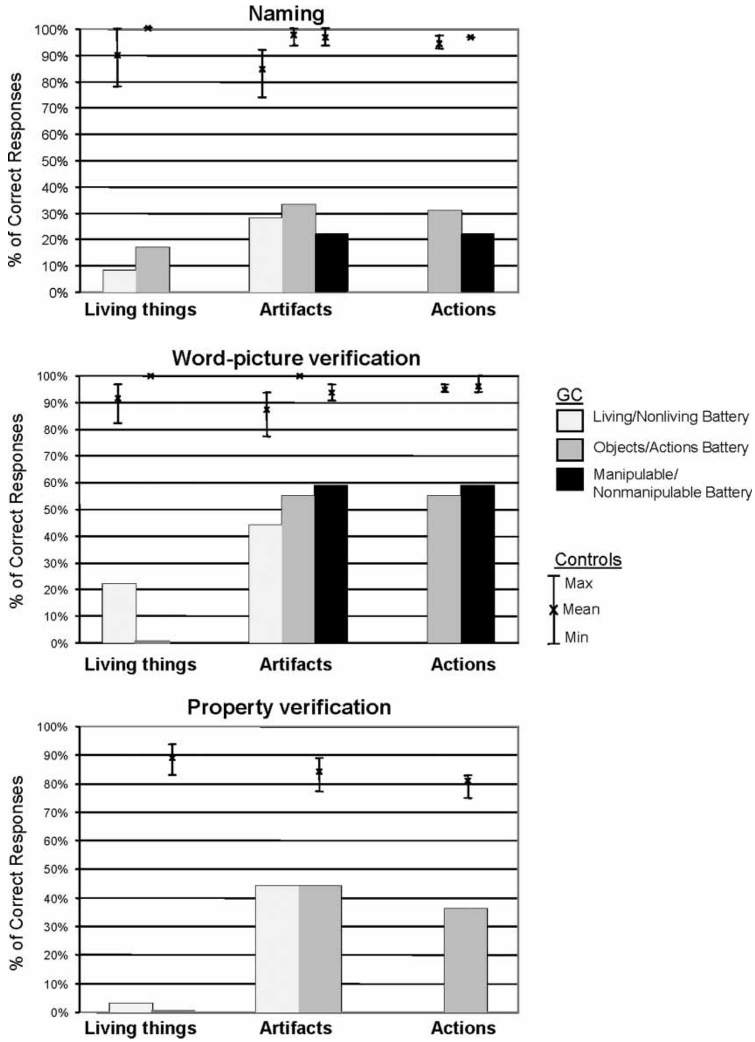

Figure 4. *Summary of G.C.'s performance for living things, artifacts, and actions across several tasks (naming, word–picture verification, property verfication) and item sets (Living/Nonliving Battery, Objects/Actions Battery, Manipulable/Nonmanipulable Battery).*

pooling both item sets, so that the analyses included 50 artifacts (18 items from the first and 32 items from the second battery) and 68 actions (36 items from the first and 32 items from the second battery). In that way, G.C.'s scores in the word–picture verification task were 58% correct for the artifacts and 57% correct for the actions, while the mean of the 5 controls was 96% for both artifacts (range = 94–98, $SD = 1.67$) and actions (range = 94–97, $SD = 1.61$). In the naming task, G.C. scored 26% correct for both the artifacts and the actions, while the controls' mean scores were 97% for the artifacts (range = 94–100, $SD = 2.28$) and 95% for the actions (range = 94–97, $SD = 1.61$). The data analyses indicated that, in the word–picture verification task, G.C. was impaired for both artifacts, $t(4) = -20.97$, $p < .0001$, and actions, $t(4) = -21.84$, $p < .0001$, but, again, far from being significantly more impaired for one or the other category of items (BSDT: $p = .93$). Likewise, in the naming task, G.C. appeared impaired for both artifacts, $t(4) = -28.51$, $p < .00001$, and actions, $t(4) = -39.02$, $p < .00001$, with no evidence of a differential impairment between both categories of items (BSDT: $p = .21$). It thus seemed quite unlikely that the nonsignificant difference between the levels of impairment for artifacts and actions was a null effect due to the small number of items in each set.

GENERAL DISCUSSION

In this study, we have assessed conceptual knowledge of concrete objects, both living things and artifacts, and concrete actions in a brain-damaged patient, G.C., presenting with a conceptual deficit. We found that, although in this patient conceptual knowledge of concrete objects first appeared disproportionately impaired compared to his knowledge of actions, only knowledge of living things among concrete objects was in fact disproportionately impaired compared to knowledge of actions—knowledge of artifacts was not differentially impaired compared to knowledge of actions. This finding showed that investigating conceptual deficits in brain-damaged patients by considering the Objects/Actions dichotomy may be misleading. Like the numerous reports of category-specific conceptual deficits for either living things or artifacts have already established (see Capitani et al., 2003), "objects" are not an unitary category within the conceptual processing system. Therefore, future neuropsychological studies should contrast patients' performance in processing action concepts to their performance in processing different categories of objects; otherwise, the study could lead to the fallacious conclusion that objects are disproportionately impaired or spared in comparison with actions, while this is the case for living or nonliving objects only.

The second key finding of this study was that, beyond his disproportionate deficit for the concepts of living things, the patient consistently presented a similar degree of impairment for the concepts of artifacts and of actions in a variety of tasks, which were as different in input and output processing modalities and demands as naming photographs, understanding words and pictures, verifying verbally presented semantic properties, and pantomiming how the artifacts were used or the actions performed. In all these tasks, the patient's performance for artifacts and actions was consistently impaired to the same degree compared to that of control subjects and consistently better than his performance for living things.

A straightforward interpretation of the patient's similar pattern of performance for the concepts of artifacts and the concepts of actions compared to the concepts of living things would be that the concepts of artifacts and of actions patterned together because they shared a processing and representational system that is distinct from the system(s) involved in processing the concepts of living things, the former being less severely damaged than the latter by brain damage. We may then ask how this shared processing system could be characterized.

According to accounts for category-specific conceptual deficits inspired by the feature-based organization (FBO) theory of conceptual organization—namely, the "sensory/functional" or "sensory/motor" account (Bird et al., 2000) and the "manipulability" account (e.g., Kellenbach et al., 2003; Saccuman et al., 2006)—the system shared by both the concepts of artifacts and the concepts of actions would be a system representing functional/motor or manipulation knowledge, on which these categories would mainly rely. Within these accounts, the patient's specific pattern of conceptual impairment would be interpreted as resulting from this system being less severely damaged than the system on which the concepts of living things rely—that is, the sensory knowledge system. However, if this were the case, functional/motor or manipulation knowledge should be less impaired than sensory knowledge in that patient—a prediction that was not supported by the findings of this study. G.C. was not less impaired for functional/motor knowledge or manipulation knowledge compared to sensory knowledge, and he did not show better knowledge for manipulable compared to nonmanipulable items. The results instead showed that all types of knowledge (sensory, functional, motor) were less impaired for both artifacts and actions than for living things.

This is not a unique case whose pattern of conceptual deficit cannot be accounted for within the feature-based theory. In their detailed review of the cases of category-specific conceptual deficits for living things compared to artifacts or the reverse, Capitani et al. (2003) showed that the vast majority typically involved to equal degrees all types of conceptual knowledge—that is, sensory/perceptual and functional/associative—in the affected categories. Our findings thus add support to the view that the domain of conceptual knowledge, and not or not only the type or modality of conceptual knowledge, constitutes one principle of conceptual organization in mind and brain (Caramazza & Shelton, 1998).

The alternative theories to FBO theory of conceptual knowledge organization that we reviewed in the introduction—namely, the theories developed within the correlated and unitary content (CUC) framework (OUCH by Caramazza et al., 1990; FUSS by Vigliocco et al., 2004; and the computational model of Devlin et al., 1998) and the domain-specific-knowledge (DSK) theory (Caramazza & Shelton, 1998)—in fact all predict that damage to a semantic category should equally affect all types of knowledge for the members of that category. However, within these alternative theories, there is no principled way to account for another feature of the patient's pattern of conceptual impairment—namely, the similar level of impairment for the concepts of artifacts and actions while the concepts of living things are disproportionately impaired. This feature clearly does not fit the predictions that could be drawn from the computational model of Devlin et al. (1998), namely, that the concepts of artifacts should dissociate from the concepts of actions following random damage, whatever its severity. Moreover, this feature of G.C.'s conceptual impairment is difficult to reconcile with the view, derived from other CUC approaches (Caramazza et al., 1990; Vigliocco et al., 2004), of a conceptual space in which the clusters of features representing the concepts of artifacts are represented closer to the clusters representing the concepts of living things than to those representing the concepts of actions—difficult, but not impossible in fact. One could propose, for instance, that the patient's pattern resulted from focal damage to several regions within the conceptual space that fortuitously affected, with equal severity, the clusters defining the concepts of actions in addition to the clusters corresponding to the different categories of artifact concepts (like manipulable artifacts or tools, vehicles, and furniture), as well as, more severely, the clustered properties defining animals, on the one hand, and plants, on the other hand. Actually, within these CUC approaches, almost any combination of disproportionately impaired/relatively spared categories could be accounted for (Caramazza & Shelton, 1998). Still not every possible combination of category-specific deficits have been reported. For instance, according to these theories, in the case of focal damage, fine-grained patterns of category specificity within the artifact domain could show up, like a category-specific deficit for manipulable (tools) or for nonmanipulable artifacts (e.g., vehicles), since these items form distinct clusters within conceptual space. Yet not only in the present case but also in all previous reported cases of a disproportionate sparing or impairment for artifacts (compared to living things), no evidence has been found for a more fine-grained distinction within the artifact category, which, incidentally, also weakens the proposal of a domain-specific system for the concepts of tools made within the DSK theory (Caramazza & Shelton, 1998).

The case Y.O.T. (Warrington & McCarthy, 1987) is often cited in the literature as a case presenting with a disproportionate conceptual impairment for manipulable compared to nonmanipulable artifacts. However, not only was the dissociation not reliable across the various comprehension tasks and items presented to the patient (Capitani et al., 2003) and the two categories of items not matched on any relevant variables, the classifications of artifact items in both categories were equivocal. In the paper, the authors spoke of "small manipulable objects" as compared with "large man-made objects", whilst in the Appendix the categories were called "indoor objects" and "outdoor objects", respectively, which in fact seems to be more accurate. "Indoor objects" indeed includes both utensils/implements (e.g., fork, paper clips, pencils, kettle, hairdryer) and furniture (chair, desk, lamp, clock, cushion). One may question whether the furniture items would be consistently classified as manipulable items (or even "small" items). We are not aware of any other case report of a patient presenting with a reliable dissociation within the artifact domain. Although musical instruments have been sometimes found to pattern differently than other artifacts in patients presenting with a living or a nonliving deficit, the data were not clear or reliable enough to document a dissociation within the artifact domain (see data and discussion on this point in Capitani et al., 2003).

In sum, current alternative approaches to FBO theory (like CUC or DSK) fail to provide a principled account for why concepts of artifacts and of actions could be impaired similarly and why the various categories of artifacts are consistently spared or impaired together. Admittedly, these features of G.C.'s conceptual impairment could merely be ascribed to chance—for example, to damage to anatomically proximal but functionally unrelated clusters of semantic properties or conceptual processing systems. This "chance account" may well turn out to be valid if it were shown, in further studies examining carefully the status of conceptual representations of artifacts compared to actions in brain-damaged patients, that the pattern of association found in our patient does not present any regularity—that is, that the concepts of artifacts and of actions are susceptible to be damaged separately or to a different degree.

Nonetheless, an alternative hypothesis should be entertained—namely, that the concepts of artifacts and of actions patterned together in our patient because the former are functionally dependent on the latter. One may assume that the concepts of artifacts cannot be learned independently from the purposeful activities they serve to achieve. Thus artifacts would derive their meaning from the knowledge of the goal or purpose of the actions they serve to realize or carried out through them: A fridge would acquire its meaning from the knowledge of what is the purpose of "cooling", a knife from the knowledge of what is the purpose of "cutting", and a bus from what is the purpose of "transporting". On this basis, the conceptual representations of artifacts would be subsumed under the conceptual representations of human actions and activities. Because of this structure, one should not observe, after brain damage, a deficit for the concepts of actions without a concomitant deficit for the concepts of artifacts—although a deficit for artifacts would not necessarily impair the concepts of actions.

Another possible way to conceive of the functional dependency between the concepts of artifacts and the concepts of actions would be to posit that they are both represented and processed by a specialized, domain-specific, conceptual system, which would be involved in creatively generating plans according to specific goals or purposes and in understanding and anticipating the results of other people's activities. To fulfil these functions, a specialized conceptual processing system would have evolved that allows the quick and efficient retrieval of conceptual knowledge related to achieving specific purposes (for additional arguments, see Vannuscorps & Pillon, 2011). Thus, this system would represent conceptual knowledge related to any kind of artifacts—tools or other manipulable artifacts (e.g., a hammer or a coat) as well as nonmanipulable artifacts (e.g., a bookcase or a car) —and any kind of purposeful actions—manual (e.g., cutting) as well as whole-body (e.g., running) actions—because all would be conceptualized as means to achieve a goal. Furthermore, this system would be domain-specific in the sense that it would store and process all kinds of conceptual knowledge related to artifacts—not only their function but also knowledge of their shape, texture, colour, weight, typical location, approximate cost, and so on—and to human actions—not only their typical cause, goal, consequences but also the typical agent involved, the needed energy, the approximate duration, emotional valence, and so on (e.g., Tranel, Kemmerer, Adolphs, Damasio, & Damasio, 2003)—because any aspect of knowledge could potentially be relevant in planning and understanding activities. Therefore, in case of damage to this domain-specific conceptual system, all types of knowledge about any type of artifacts and human activities should be similarly impaired (everything else being equal).

Our proposal has some resemblance to the praxis conceptual system suggested by Roy (1983; see also Roy & Square, 1985) since this praxis conceptual system is also assumed to represent some aspects of both artifact and action knowledge (see also the "action semantics" of Rothi, Ochipa, & Heilman, 1991). However, this system, which is actually part of a model of limb praxis, only represents knowledge relevant to limb praxis (e.g., knowledge of the specific mechanical advantages provided by tools or of the specific mechanical requirements to achieve a manual action goal on an object), while, in our view, any kind of conceptual knowledge (e.g., perceptual, functional, associative knowledge) related to all artifacts and actions, be they relevant to limb praxis or not (e.g., be they transitive manual actions or intransitive actions performed with the whole body) would be represented in this domain-specific conceptual system.

The proposal of a shared conceptual system for artifacts and actions is compatible with extant findings from neuroimaging studies that consistently reported a bilateral although left-dominant fronto-parieto-temporal network involved in processing knowledge of both artifacts (most often, but not always, tools) and actions in a great variety of tasks (see the meta-analysis by Binder, Desai, Graves, & Conant, 2009, and the review by Noppeney, 2008). Thus, when contrasted to the processing of living things in tasks like picture naming or word or picture association, artifact processing resulted in specific activity in the mostly left premotor/motor cortex, inferior parietal cortex, and/or posterior middle temporal regions (e.g., Chao & Martin, 2000; Creem-Regehr & Lee, 2005; Kalénine et al., 2009; Lewis, Brefczynski, Phinney, Janik, & DeYoe, 2005; Moore & Price, 1999; Mummery, Patterson, Hodges, & Price, 1998). The same three regions showed specific activity during action observation compared to nonaction stimuli and during naming, auditory word comprehension, and conceptual judgement of action names compared to nonaction names (Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008; Damasio et al., 2001; Grèzes & Decety, 2001; Kable et al., 2005; Noppeney et al., 2005).

The precise function of each part of this network is still poorly understood (e.g., Kable et al., 2005; Oliveri et al., 2004) and has only recently started to be addressed (e.g., Assmus, Giessing, Weiss, & Fink, 2007; Bedny et al., 2008; Kalénine et al., 2009; Phillips, Humphreys, Noppeney, & Price, 2002; Postle, McMahon, Ashton, Meredith, & de Zubicaray, 2008; Tomasino, Fink, Sparing, Dafotakis, & Weiss, 2008; Tomasino, Werner, Weiss, & Fink, 2007). A preliminary generalization of the findings seems to indicate that the artifact- or action-specific activity found in the left premotor/motor and parietal regions is task dependent and context sensitive; they could reflect mental motor imagery (Oliveri et al., 2004; Tomasino et al., 2008; Tomasino et al., 2007) or motor attentional processes (Kellenbach et al., 2003) induced by the task or by the subject's strategy. On the other hand, the left middle posterior temporal region appears to have a critical role in the retrieval of conceptual knowledge of both artifacts and actions. Specific activity within this region was found during retrieval of conceptual knowledge related to both manipulable (e.g., scissors) and nonmanipulable artifacts (e.g., traffic light; Kellenbach et al., 2003) and during retrieval of conceptual knowledge related to both hand actions and whole-body actions (Corina et al., 2007; Noppeney et al., 2005). Strong activity within the same region was also found during semantic judgements related to five classes of verbs (running verbs like *jog*, speaking verbs like *whisper*, hitting verbs like *poke*, cutting verbs like *slice*, and change of state verbs like *shatter*) varying with respect to the semantic features of action, motion, contact, change of state, and tool use (Kemmerer, Gonzalez Castillo, Talavage, Patterson, & Wiley, 2008). These results suggest that activity in this region is not dependent on the specific sensorimotor features of artifacts and actions and may thus reflect the retrieval of property- and modality-independent representations of artifacts and actions (see also Bedny et al., 2008; Binder et al., 2009; Mummery et al., 1998). Furthermore, in a lesion study, Tranel and colleagues (2003) found that the highest area of lesion overlap in patients who had impaired knowledge for both tools and actions was in the left middle posterior temporal region. Thus this region—which was damaged in G.C.—may constitute the neural substrate of a domain-specific conceptual system representing both artifacts and actions, which would be coupled with the perceptual processes specialized in the analysis of agents' motion and located in the superior temporal sulcus region (Allison, Puce, & McCarthy, 2000).

These empirical generalizations may seem contradictory with another generalization stating that neuroimaging studies consistently found a dissociation in neural activity between the concepts of objects and actions (e.g., Vigliocco et al., 2011). The contradiction partly stems from the equivocal use of the word "object". Actually, to our knowledge, very few neuroimaging studies have contrasted directly artifact and action items. For example, Kable et al. (2002) investigated the neural substrates of action knowledge by contrasting the activity elicited by action words or pictures with that elicited by "object" words or pictures during a conceptual matching task. They found greater activity in human MT/MST (medial temporal/medial superior temporal cortex) for action than for object pictures and greater activity within the posterior middle and superior temporal gyri for action words than for object words. However, the "object" condition was composed of both artifacts and living things (plants and animals). These results obtained with action and object words were replicated in a further study (Kable et al., 2005, Experiment 1) in which action words were contrasted to "object" words that were living things and food. Assmus et al. (2007) also found differential activity during the semantic processing of action pictograms compared to pictograms of manipulable and nonmanipulable "objects" (collapsed), but the nonmanipulable "objects" included pictograms of buildings, vehicles, animals, and humans. In these studies, it is thus difficult to know whether the specific activity found for action items was driven by a difference of activity with each category of objects, living and nonliving, or only with one of them (say, living things). As for Bedny et al. (2008), they contrasted separately animals, tools, and natural kinds to different kinds of verbs (action, change-of-state and mental verbs), but there was no contrast between action verbs and tools. Among the studies in which artifacts and actions were directly contrasted, two found a greater MT+ activity for actions than artifacts (Damasio et al., 2001; Tranel, Martin, Damasio, Grabowski, & Hichwa, 2005), but the task was picture naming, and the difference in the activation pattern elicited by artifacts and actions could be ascribed to the difference in visual processing between pictures of artifacts and pictures of actions (see, for direct evidence supporting this interpretation, Kable et al., 2002; Liljeström et al., 2008). In other studies contrasting artifacts with actions in picture naming (Saccuman et al., 2006) or word categorization (Tyler et al., 2003), no distinct neural network was found. Finally, one study (Kable et al., 2005, Experiment 2) contrasted artifact and action words during a semantic matching task and found distinct areas of activity for both categories of words in the posterior lateral temporal cortex, which, however, overlapped in the middle temporal gyrus—an observation that is consistent with our hypothesis that this region may constitute the neural substrate of a domain-specific conceptual system representing both artifacts and actions.

As for the neuroimaging studies having investigated the neural correlates of the noun/verb distinction (for a recent review, see Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011), leaving behind the issue of whether the differences that were found reflected a conceptual or a grammatical category distinction, one cannot still interpret any findings as possibly reflecting a "artifact versus action" conceptual distinction (and, in most cases, not a "object versus action" conceptual distinction either), because in all the studies where this information was provided, the noun condition to which the verb condition was contrasted was not composed only or not composed at all of artifacts (or even concrete objects). In some studies, the noun set included both concrete and abstract nouns that were contrasted to a verb set composed of concrete and abstract verbs (Bedny & Thompson-Shill, 2006; Perani et al., 1999). In other studies, verbs were contrasted to a noun set including both living things and artifacts (Berlingeri et al., 2008; Shapiro, Moo, & Caramazza, 2006; Tyler, Russel, Fadili, & Moss, 2001), both nouns and adjectives (Davis, Meunier, & Marslen-Wilson, 2004), or only abstract nouns (Burton, Krebs-Noble, Gullapalli, & Berndt, 2009; Li, Jin, & Tan, 2004). In other studies, the composition of the set of nouns as regards semantic category was not specified (Palti, Ben Shachar, Hendler, & Hadar, 2007; Shapiro et al., 2005; Tyler, Bright, Fletcher, & Stamatakis, 2004; Warburton et al., 1996).

Previous findings from neuropsychological studies might also seem, at first glance, to invalidate our hypothesis of a common conceptual system for artifacts and actions. First, there are findings in the tradition of apraxia research showing that patients could name and recognize artifacts—which suggested that conceptual knowledge of artifacts was spared in these patients—while they could not demonstrate how to use them—which suggested that "action-related knowledge" for artifacts was impaired (e.g., Negri et al., 2007; Rosci, Chiesa, Laiacona, & Capitani, 2003). These facts may seem to contradict our hypothesis according to which the conceptual representations of artifacts are subsumed under the conceptual representations of human actions. In this context, one should not observe, after brain damage, a deficit for the concepts of actions without a concomitant deficit for the concepts of artifacts. However, in these cases with apraxia, "action-related knowledge" that was impaired in the patients does not refer to the same notion as our notion of "concepts of action". "Action-related knowledge" refers to knowledge or/and execution of the skilled movements that must be performed to achieve a given activity with a given artifact, while by "concepts of action" we mean all kinds of conceptual knowledge related to a category of purposeful activities (an action), which includes knowledge of its purpose, causes, and consequences, the artifacts, people, and instruments its generally involves, the typical context in which it takes place, its emotional content, and so on (Tranel et al., 2003). Our hypothesis could be rejected if it were shown that patients could name and recognize artifacts without retrieving conceptual knowledge about the action they serve to realize (e.g., if it were shown that they could name a knife without knowing that it is for "cutting" and knowing what "cutting" is about).

Second, although no previous neuropsychological study of patients presenting with a conceptual impairment has formally assessed and contrasted knowledge of living things, artifacts, and actions in the same design, a few studies reported some data related to the assessment of artifact and action processing in brain-damaged patients. We already mentioned the study by Ferreira et al. (1997), which reported on three patients whose performance in naming was impaired for animals and spared for both tools and actions. That tools and actions patterned together in comparison with animals in the case of damage to the conceptual system is consistent with our hypothesis. However, three studies may seem to report a pattern suggesting that tool and action concepts may be separately damaged.

The first one, by Tranel et al. (2003), reported that among 26 patients with impaired action concepts, only 6 also showed impaired concepts of tools. However, there are several aspects in the methodology used in this study that may be questioned. First, knowledge of tools and of actions was assessed with different tasks, which probably differed in both difficulty and the processing components involved. Thus, tool knowledge was assessed by presenting the patients with a picture of a tool and asking them to identify it (i.e., either to name it or to provide a detailed description of the object). On the other hand, action knowledge was assessed with (a) a "Picture Attribute Test", in which the patients were presented with two colour photographs of actions and were asked to choose the one that best met certain criteria (e.g., Which action would make the loudest noise?), and (b) a "Picture Comparison Test", in which the patients had to select one from among three photographs that was different from the other two. Second, a patient was deemed to have impaired concepts of actions if her/his performance was below a cut-off score for either one or both of the tests. (The cut-off score was computed on the basis of the data from the 90 brain-damaged patients participating in this study, not on the basis of data from healthy subjects, which is a questionable method.) Among the 26 subjects that fitted this criterion, 6 were impaired on just the Picture Attribute Test, 11 on just the Picture Comparison Test, and only 9 on both tests. The question could be raised whether the subjects who were impaired on only one test did have damage to action conceptual knowledge rather than to some other processing component specifically involved in each test. Third, tool and action items were not matched on relevant variables such as familiarity or imageability, and performance for both categories of items was not compared within each patient. Yet if a patient were slightly impaired for one category and not impaired for another, the difference between both categories might turn out to be nonsignificant. Finally, the functional locus of the deficit for actions and/or tools was not assessed; in particular, one cannot rule out that a number of patients with impaired action processing presented a preconceptual deficit in recognizing or inferring the movements in the static pictures of actions (d'Honincthun & Pillon, 2008).

In the second study, Bi, Han, Shu, and Caramazza (2007) reported on the case of Z.B.L. and claimed that his pattern of performance supported the hypothesis that tool and action concepts can be damaged independently. This conclusion, however, was not warranted by the results. First of all, there was no one task, in that study, that comprised a specific set of tool items. The study first included two picture naming tasks contrasting nouns and verbs (objects and actions) and in which the composition of the noun set was not reported; however, according to the available examples of items, it seems that the noun set comprised both living things and artifacts. Then, there was a picture naming task and an attribute judgement task both contrasting animals and artifacts. In both these tasks, the artifact set included tool items that were mixed with other artifacts like clothing, furniture, kitchenware, vehicles, and so on, and no separate result for tools compared to other artifacts was reported. Second, and more importantly, action and artifact (or tool) items were never directly matched or contrasted in any task or by any statistical analysis: Actions were tested in the two noun/verb picture naming tasks, and artifacts versus animals were tested in another picture naming and an attribute judgement task. The results showed that Z.B.L.'s performance in naming was impaired for both nouns and verbs, although it was worse in naming nouns (41% and 37%, depending on the naming task) than verbs (68% and 80%). Moreover, the patient's performance was impaired in naming both animals and artifacts, and it was more impaired for artifacts (44%) than animals (57%). In the attribute judgement task, Z.B.L.'s performance was impaired for artifacts (73%) but not for animals (83%). This pattern suggested that Z.B.L. probably had a conceptual impairment for artifacts and a further impairment in retrieving the phonological word-form of both nouns and verbs, but especially nouns. There are no data, however, that could inform us about the status of verbs/actions at the conceptual level and, in particular, no data that could rule out that actions might be impaired like artifacts.

The third case report that has to be discussed here is the case E.A. (Laiacona & Caramazza, 2004). E.A. presented with a category-specific conceptual deficit for animals. Moreover, like Z.B.L., E.A. showed worse performance in naming nouns (42%) than verbs (82%); he was also worse at naming the artifacts (22%) than the actions (85%) presented in the same pictures. However, E.A. was unimpaired in a word/picture matching task for both artifacts (98%) and actions (100%), which suggested that his disproportionate impairment in naming nouns/objects compared to verbs/actions was caused by a word-form retrieval deficit affecting nouns more than verbs, not by a conceptual deficit affecting artifacts more than actions. This pattern of a grammatical category-specific deficit showing up in naming and not in a comprehension task is far from being uncommon (e.g., Berndt et al., 1997; Bird et al., 2000; Breedin, Saffran, & Schwartz, 1998; Miceli, Silveri, Nocentini, & Caramazza, 1988; Shapiro & Caramazza, 2003a, 2003b; Zingeser & Berndt, 1988), like the grammatical category-specific deficits showing up only in one modality, spoken or written, of naming (e.g., Caramazza & Hillis, 1991; Collina, Marangolo, & Tabossi, 2001; Marshall, Pring, & Chiat, 1998; Rapp & Caramazza, 1998, 2002). 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 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, Shelton, & Caramazza, 2000).

Overall, the patterns of performance shown by Z.B.L. and E.A. might indicate the existence of two independent functional loci of deficit in both patients. Z.B.L. had a deficit at the conceptual level of processing affecting artifacts (and, possibly, actions) more than animals and an additional deficit at the level of the phonological form retrieval affecting nouns more than verbs. On the other hand, E.A. had a deficit at the conceptual level affecting animals more than artifacts and actions, further to an additional deficit at the level of the phonological form retrieval affecting nouns more than verbs, like in Z.B.L.

We acknowledge that these interpretations are speculative given the lack of relevant data. It is clear that further single and multiple case studies of patients with a conceptual impairment, whose knowledge of various categories of objects and actions should be carefully tested across distinct tasks, are needed to evaluate the hypothesis of a common conceptual system for artifacts and actions.

To conclude, we have reported the single-case study of a patient presenting with a conceptual impairment that was disproportionate for living things compared to artifacts and actions, which were both similarly impaired. This pattern first indicated that investigating conceptual deficits by contrasting concepts of "objects" as a unitary category to concepts of actions could lead to fallacious conclusions and thus should encourage further studies of patients presenting with a conceptual impairment to assess conceptual knowledge of the three categories of objects (animals, plants, artifacts) separately in comparison to conceptual knowledge of actions. Second, the pattern of conceptual impairment reported here suggested that the conceptual knowledge of artifacts and of actions may be functionally and neurally related one to the other. We advanced the hypothesis that the concepts of artifacts and of actions are represented and processed by a common, domain-specific conceptual system that represents knowledge relevant for achieving goals and purposes and for understanding others and which may be located in the left middle posterior temporal gyrus. Much more additional evidence is needed, however, before this hypothesis—derived from a pattern of conceptual impairment that is reported for the first time—could be confirmed.

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APPENDIX

Examples of statements probing sensory and functional knowledge in the property verification task with the items of the Objects/Actions Battery

Item	*True/false*	*Sensory property*	*Functional property*
Objects			
Cow	True	The cow has horns	The cow is reared for its milk
	False	The cow has a mane	The cow is used for races
Orange	True	The orange has a thick skin	The orange is used for making juice
	False	The orange has a thin skin	The orange is used for making cider
Kettle	True	The kettle is made of metal	The kettle is used for heating water
	False	The kettle is made of porcelain	The kettle is used for pouring tea
Pouffe	True	The pouffe is a soft seat	The pouffe usually stands in a lounge
	False	The pouffe is a wood seat	The pouffe usually stands in a kitchen
Actions			
Grating	True	When grating, one rubs something on small blades	Grating something is for reducing it into powder or small pieces
	False	When grating, one plunges a utensil into food	Grating is for mixing all ingredients together
Pushing	True	When pushing something, one presses on it with the hands, for example	Pushing something is for moving it, for example
	False	When pushing something, one reaches a moving thing	Pushing something is for preventing it to escape, for example
Stretching	True	When stretching, one spreads the arms very widely	Stretching is for relaxing
	False	When stretching, one opens the mouth widely	One stretches when one feels sleepy
Kissing	True	When kissing, one touches someone's cheek with his/her mouth	Kissing is for expressing one's love
	False	When kissing, one shakes his/her hand in the air	Kissing is for making a polite gesture