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A domain-specific system for representing knowledge of both man-made objects and human actions. Evidence from a case with an association of deficits

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ABSTRACT

We report the single-case study of a brain-damaged individual, JJG, presenting with a conceptual deficit and whose knowledge of living things, man-made objects, and actions was assessed. The aim was to seek for empirical evidence pertaining to the issue of how conceptual knowledge of objects, both living things and man-made objects, is related to conceptual knowledge of actions at the functional level. We first found that JJG's conceptual knowledge of both man-made objects and actions was similarly impaired while his conceptual knowledge of living things was spared as well as his knowledge of unique entities. We then examined whether this pattern of association of a conceptual deficit for both man-made objects and actions could be accounted for, first, by the "sensory/functional" and, second, the "manipulability" account for category-specific conceptual impairments advocated within the Feature-Based-Organization theory of conceptual knowledge organization, by assessing, first, patient's knowledge of sensory compared to functional features, second, his knowledge of manipulation compared to functional features and, third, his knowledge of manipulable compared to non-manipulable objects and actions. The later assessment also allowed us to evaluate an account for the deficits in terms of failures of simulating the hand movements implied by manipulable objects and manual actions. The findings showed that, contrary to the predictions made by the "sensory/functional", the "manipulability", and the "failure-of-simulating" accounts for category-specific conceptual impairments, the patient's association of deficits for both man-made objects and actions was not associated with a disproportionate impairment of functional compared to sensory knowledge or of manipulation compared to functional knowledge; manipulable items were not more impaired than non-manipulable items either. In the general discussion, we propose to account for the patient's association of deficits by the hypothesis that concepts whose core property is that of being a mean of achieving a goal – like the concepts of man-made objects and of actions – are learned, represented and processed by a common domain-specific conceptual system, which would have evolved to allow human beings to quickly and efficiently design and understand means to achieve goals and purposes.

1. Introduction

Neuropsychological reports of category-specific conceptual deficits have constituted an important source of evidence for theories of conceptual knowledge organization in the human mind and brain. The most frequently reported cases were those of brain-damaged individuals who presented a selective or disproportionate conceptual impairment for one category of objects, like animals, plant life, or man-made objects, compared to another (see for review, Capitani, Laiacona, Mahon, & Caramazza, 2003), thereby informing theories about the organization of *object* knowledge in the mind and brain (Caramazza & Shelton, 1998; Humphreys & Forde, 2001; Martin, Ungerleider, & Haxby, 2000; Simmons & Barsalou, 2003; Warrington & McCarthy, 1987). Much less neuropsychological evidence has been gathered as regards how conceptual knowledge pertaining to human actions[1] may break down after brain damage and, in particular, how such knowledge is related to object knowledge. We report here the single-case study of a brain-damaged individual, JJG, whose pattern of conceptual impairment, which included impaired action knowledge, provided evidence relevant to this issue.

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[1] Throughout this paper, the term "actions" will refer to categories of human goal-directed activities that are expressed by a single verb (e.g., *drinking* or *grating*). It thus will not refer to single movements (e.g., raising the arm) or more specific activities like the ones expressed by verbal phrases (e.g., *drinking wine* or *grating cheese*).

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Three main positions may be distinguished across extant theories of conceptual knowledge organization, as regards the issue of how object and action conceptual knowledge is related at the functional and/or neural level – the first positing segregated conceptual representations for objects and actions, the second positing partly overlapping representational or processing systems for knowledge of one category of objects, i.e., man-made objects, and of actions, and the third, a shared but unspecific system for both man-made objects and actions.

The first position was formulated within the context of studies reporting on grammatical category-specific deficits, that is, naming and/or comprehension deficits that selectively or disproportionately impaired one grammatical category of words, nouns or verbs, compared to the other (for recent reviews, see Druks, 2002; Mätzig, Druks, Masterson, & Vigliocco, 2009). Because in almost all these reports, the material included concrete nouns and concrete verbs, which correspond to objects and actions, respectively, a number of authors advanced that, for at least some of these reported cases, the double noun/verb dissociation in fact reflected an underlying segregation between object and action concepts within the conceptual system (Damasio & Tranel, 1993; Kable, Kan, Wilson, Thompson-Schill, & Chatterjee, 2005; Laiacona & Caramazza, 2004; McCarthy & Warrington, 1985; Rapp & Caramazza, 1998; Vigliocco, Vinson, Lewis, & Garrett, 2004; see for discussion, Pillon and d'Honincthun, submitted for publication-a). However, in the studies reporting grammatical category-specific deficits, the set of nouns/objects that was contrasted to the set of verbs/actions in fact included, most of the times and in various proportions, both living and non-living objects. The results were not reported or analyzed according to each category of nouns/objects, like it was assumed that all categories of objects shared a common representational system. Nonetheless, it is well known that, within the category of objects, knowledge of living and non-living things may dissociate following brain damage. It is thus unclear how the term "object" must be understood in this proposal of a conceptual fractionation along the "Object/Action" dimension. In the more recent proposal by Vigliocco et al. (2004), this point was made clearer. Thus, according to their "Featural and Unitary Semantic Space" (FUSS) hypothesis, the conceptual representations of each category of objects – animals, vegetables, man-made objects – occupy distinct areas within the "lexico-semantic space", which are themselves still more segregated from the areas sustaining the conceptual representations of actions. In that way, a focal "lesion" to this heterogeneous space may impair the conceptual representations of all or only one of the categories of objects by sparing the conceptual representations of actions or the reverse, i.e., impair the conceptual representations of actions by sparing those of all or only one category of objects.

The second position – partly overlapping representational or processing systems for knowledge of man-made objects and of actions – can be found within two different theoretical frameworks. First, within the currently most influential view on conceptual knowledge organization, which we will call here the Feature-Based Organization (FBO) theory, knowledge of one category of objects, that is, man-made objects, and knowledge of actions would be represented in overlapping systems by virtue of their being both weighted of a specific kind of conceptual features, like functional or manipulation features. There are several variants of this theory, which differ on a number of points. For example, conceptual knowledge may be conceived of as amodal representations (e.g., Farah & McClelland, 1991) or modality-specific representations encoded nearby (e.g., Martin et al., 2000) or in the sensory and motor systems (e.g., Allport, 1985; Warrington & McCarthy, 1987). The number and kind of property dimensions driving the organization of conceptual knowledge may also vary across the various formulations of the theory, from one dimension like "sensory *vs.* non-sensory" (e.g., Bird, Howard, & Franklin, 2000) or "visual *vs.* functional" (Farah & McClelland, 1991; Warrington & McCarthy, 1983; Warrington & Shallice, 1984) properties, to multiple dimensions like form, color, motion, function, and motor properties (e.g., Allport, 1985; Humphreys & Forde, 2001; Martin et al., 2000; Warrington & McCarthy, 1987). However, all the variants share the two following assumptions: first, knowledge is represented in a distributed way over various functional and neural systems each representing a distinct kind of featural knowledge, say, sensory (visual, auditory, somato-sensory, olfactory), functional, manipulation, or motor knowledge; second, the various categories of concepts are differentially weighted of each kind of feature and, hence, represented in partially distinct systems. The differential weighting of features reflects the relative importance of the various types of semantic properties within the definition of a given concept (Bird et al., 2000; Farah & McClelland, 1991; Warrington & McCarthy, 1983; Warrington & Shallice, 1984) or the relative involvement of the various sensory-motor modalities of experience during the acquisition of that concept (Allport, 1985; Crutch & Warrington, 2003; Damasio & Tranel, 1993; Gainotti, Silveri, Daniele, & Giustolisi, 1995; Warrington & McCarthy, 1987). Thus, for example, Bird et al. (2000) assumed that the concepts of living things have a greater weighting of sensory compared to functional features and the concepts of actions a greater weighting of functional compared to sensory features, while the concepts of nonliving things (man-made objects) have an intermediate sensory-to-functional ratio. This proposition predicts that, in case of damage to the functional system, man-made objects as well as actions should be impaired, although man-made objects would be *less* impaired than actions, while living things should be relatively spared. In another variant of the theory, the primary dimension determining the organization of conceptual knowledge is manipulability (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 non-manipulable 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 man-made objects and actions that are weighted of manipulation features would mainly rely on a shared system, a manipulation knowledge system (see also Buxbaum & Saffran, 2002). In case of selective damage (or sparing) to this system, the expected pattern of separation between conceptual categories thus would not be between the concepts of man-made objects and the concepts of actions, but between the concepts that are weighted of manipulation features (i.e., both man-made objects and actions which utilization or realization requires fine hand movements) and those that are not (i.e., both man-made objects and actions that do not involve hand movements). 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 (sensory, functional, or manipulation) that is assumed to be crucial in the processing of the disproportionately impaired category.

Second, within the framework of the motor simulation theory (e.g., Gallese & Lakoff, 2005; Rizzolatti & Craighero, 2004; Rizzolatti, Fogassi, & Gallese, 2001), accessing the conceptual content of both manipulable objects and actions would be dependent on *motor production* processes involved in the actual use of objects and the actual execution of actions. The conceptual content of manipulable objects and actions would be retrieved by the covert simulation of the production of the movements implied by object manipulation or action execution. Thus, within this perspective, conceptual processing of manipulable objects and, specifically, manual actions should depend on the ability to covertly simulate hand/arm movements. Therefore, in case of damage to these motor simulation processes, knowledge of both manipulable objects and manual actions should be impaired and such impairment should be associated with upper limb apraxia, in particular, an impairment in recognizing and performing the hand/arm movement associated with manipulable objects and manual actions.

In other words, both the above variants of the FBO theory and the motor simulation theory assume that the concepts of man-made objects and of actions share a specific kind of representation or process that has a crucial role in their overall representation and processing – functional or manipulation feature representations, within the "sensory/functional" or the "manipulability" variant of the FBO theory, and hand/arm movement simulation processes, within the motor simulation theory.

The third position, derived from the domain-specific knowledge theory (Caramazza & Shelton, 1998), would also predict that, in case of brain damage, knowledge of man-made objects should pattern with knowledge of actions, but for another principled reason. This theory assumes that the organization of conceptual knowledge in the brain results from evolutionary pressures that led to specific adaptations for solving, quickly and efficiently, computationally complex survival problems (for example, avoiding predators and finding food). These adaptations would consist in specialized perceptual and cognitive processes and dedicated domain-specific neural circuits for processing knowledge of animals, plant life, and conspecifics, three domains in which quick and efficient recognition are thought to have fitness value. On this view, man-made objects as well as actions are not *a priori* candidate domains for dedicated circuits. Knowledge related to both these categories would thus be represented and processed by domain-general, non-specialized, cognitive processes and neural circuits. Thus, this theory predicts that, everything else being equal, brain damage should not differentially disrupt the concepts of man-made objects and the concepts of actions although both categories of concepts could dissociate from the concepts of animal and/or plant. Furthermore, in such a context, other kinds of concepts that are not assumed to be sustained by a specialized system, say, geographical knowledge, should be damaged as well.[2] In other words, the association of a knowledge deficit for man-made objects and for actions should in fact result from the selective preservation of animal and plant knowledge, which are processed by specialized conceptual systems. Recently, the proponents of the theory suggested that tools, within the broader category of man-made objects, also could be a category of objects whose efficient recognition and use had fitness value in human evolution and, hence, could be processed by a dedicated domain-specific conceptual system (Mahon & Caramazza, 2009). In that case, knowledge of tools could dissociate from knowledge of other man-made objects (i.e., furniture, vehicles, and clothing) in the condition of brain damage. However, in any case, within this theoretical framework, selective damage to a category of concepts will equally affect all types of knowledge about that category.

In the single-case study we are to report here we assessed knowledge of living things, of man-made objects, and of actions in a brain-damaged patient, JJG, presenting with a conceptual deficit. After a detailed case report, we will show that JJG's conceptual knowledge of both man-made objects and actions was severely impaired while his conceptual knowledge of living things was spared as well as his knowledge of unique entities. We then examined whether this pattern of association of a conceptual deficit for both man-made objects and actions could be accounted for, first, by 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 by assessing, first, the patient's knowledge of sensory compared to functional features, second, his knowledge of manipulation compared to functional features and, third, his knowledge of manipulable compared to non-manipulable items. The later assessment also allowed us to evaluate an account for the deficits in terms of failures of simulating the hand movements implied by manipulable objects and manual actions.

The "sensori/functional" account for category-specific conceptual impairments predicts that a conceptual deficit for man-made objects and actions in the presence of spared knowledge of living things should (i) affect all types of man-made objects (i.e., both manipulable and non-manipulable man-made objects) and actions (i.e., both manipulation/manual and non-manipulation/manual actions), although man-made objects should be less severely impaired than actions and (ii) be associated with a disproportionate loss of knowledge of functional compared to sensory features whereas the "manipulability" account predicts that the deficit should be (i) selective to manipulable man-made objects and manipulation actions and (ii) associated with a disproportionate loss of manipulation compared to functional knowledge. As for the "failure-of-simulating" account, it predicts that a conceptual deficit for man-made objects and actions should be (i) selective to manipulable man-made objects and manual actions and (ii) associated with upper limb apraxia.

The findings showed that, contrary to the predictions made by the "sensory/functional", the "manipulability", and the "failure-of-simulating" accounts for category-specific conceptual impairments, the patient's association of deficits for both man-made objects and actions was not associated with a disproportionate impairment of functional compared to sensory knowledge or of manipulation compared to functional knowledge; the patient was not more impaired for manipulable compared to non-manipulable items either, although he did present with upper limb apraxia. In the general discussion, we will propose to account for the patient's association of deficits by the hypothesis that all kinds of concepts whose core property is that of being a mean of achieving a goal are learned, represented, and processed by a common domain-specific conceptual system, which would have evolved to allow human beings to quickly and efficiently design and understand means to achieve goals and purposes.

2. Case report

JJG is a right-handed man with a Master's Degree in Engineering, and was 59 years old in October 2007, when this study began. In 1999, he had suffered from an ischemic stroke in the region of the right posterior artery, without apparent sequel. In

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[2] These predictions may seem too strong and could be qualified if additional assumptions were made about the internal organization of the domain-general conceptual system. Actually, the domain-specific knowledge theory does not exclude the possibility that some heterogeneity emerges within the conceptual space of semantic features as a result of systematic differences in the distribution of semantic features across the various categories of concepts, which could lead to dissociations in case of damage. Thus, concepts from one category (i.e., man-made objects) may have more strongly intercorrelated semantic features than concepts from another category (i.e., actions), and this could have significant consequences in the condition of brain damage. For example, the category with strongly intercorrelated features could be more vulnerable and more likely to be damaged as a category (Caramazza & Shelton, 1998) or, on the contrary, more resilient to mild damage compared to the category with more weakly correlated features (Devlin, Gonnerman, Andersen, & Seidenberg, 1998). Moreover, it may be assumed that clusters of concepts sharing properties are represented in close proximity in the conceptual space and, thereby, would be impaired together while other clusters of concepts would be spared, in case of damage (Caramazza et al., 1990). Based on a feature cluster analysis (Vigliocco et al., 2004), this assumption would predict – like the "Featural and Unitary Semantic Space" hypothesis (Vigliocco et al., 2004) – that knowledge of man-made objects and of actions could be damaged separately.

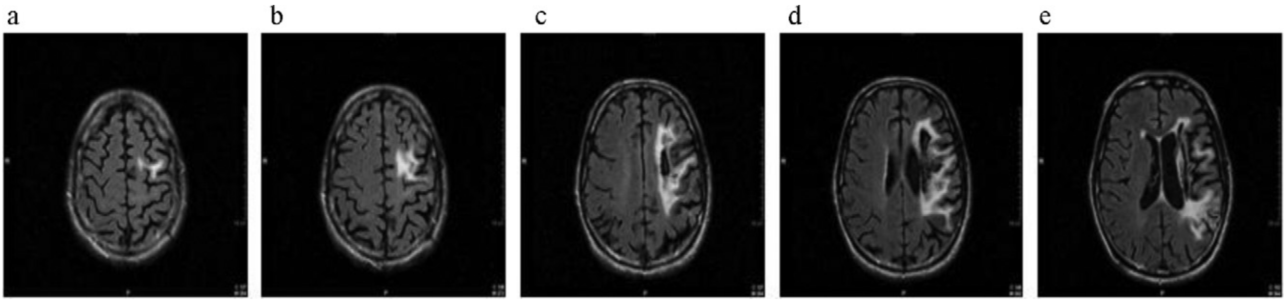

Fig. 1. Transversal sections of JJG's brain, showing the lesion in the left prefrontal cortex (a, b) and the extensive superficial and deep lesion in the left temporal lobe (c, d, e).

December 2005, he suffered from a second ischemic stroke in the region of the left middle cerebral artery which left him with a right hemiplegia, upper limb apraxia, and global aphasia. In 2009, an MRI scan showed micro- and macrocystic gliosis involving almost the whole profound and superficial left sylvian territory. This included the putamen, part of the pallidum, the caudate nucleus, a large part of the thalamus, the corona radiata, the centrum ovale, the insula, the superior and middle temporal gyri and part of the inferior temporal gyrus, the supramarginal and angular gyri, the precentral gyrus, the middle frontal gyrus and part of the inferior frontal gyrus. Subcortical gliosis also extended to the superior frontal gyrus and the root of postcentral gyrus. An important atrophy of the left cortico-spinal tract as well as a passive enlargement of the left lateral ventricule was observed (Fig. 1).

The neuropsychological examinations performed in October 2007 (see Table 1) identified preserved visual episodic and short-term memory (verbal memory could not be tested because of JJG's word-finding and reading difficulties) and no executive dysfunction. Low-level visual processing was preserved on the Minimal Feature View task (B.O.R.B., Riddoch & Humphreys, 1993). JJG's ability to access the structural description system (Humphreys, Riddoch, & Quinlan, 1988) was also preserved: he performed in the normal range with the items of the *Batterie de Décision Visuelle d'Objets* (Bergego, Pradat-Diehl, & Ferrand, 2006) containing 28 living and 44 man-made objects and 72 non-objects, as well as with another 144-items decision task comprising four subcategories of objects and non-objects (animals, fruit/vegetables, vehicles, and implements; Samson, Pillon, & De Wilde, 1998).

JJG's visual processing of gestures and access to the stored representation of gestures were good: he performed similarly to control subjects when presented with a videotaped presentation of 30 meaningful and 30 meaningless gestures and asked to tell whether they were meaningful or not (Peigneux & Van der Linden, 2000). He also performed almost flawlessly when asked to reproduce displayed postures on a model, which shows that his visuo-gestural analysis and knowledge of the body were intact (Goldenberg, 1995). However, JJG showed severe difficulties in gesture production, whatever the modality of presentation of the stimuli (i.e., producing gestures on verbal command or on imitation) and the type of gestures (i.e., meaningful or meaningless). He scored between 0 and 3/20 across the various production tasks (Table 1). The error analysis, performed with Peigneux and Van der Linden's (2000) scheme (adapted from Rothi, Ochipa, & Heilman, 1997), first revealed a similar rate of partial perseveration errors (mostly, perseveration of the manual or digital configuration or of the movement of the preceding gesture) in producing gestures to verbal command (17%) and in imitating meaningless (17%) or meaningful (21%) gestures, which suggested an impairment located at the level of the output gestural buffer (Cubelli, Marchetti, Boscolo, & Della Sala, 2000). In the imitation task, the other main types of errors were temporal and spatial errors for both meaningless (80%) and meaningful (66%) gestures. However, in producing gestures on verbal command, the temporal and spatial errors were less frequent (33%) while hesitation errors and non-responses appeared far more frequently (42%) than in imitation tasks (3% and 5% hesitation errors in imitating meaningless and meaningful gestures, respectively). This error pattern suggested additional impairments in retrieving stored information about how to perform actions or manipulate objects and in planning accurately recognized gestures for production.

Table 1
Neuropsychological data of patient JJG (October 2007).

Tests	JJG's score	Control's mean (CM) or JJG's percentile (*P*) or *z*-score
Short term memory		
Spatial span[a]		
Forward	5	$z = -1$
Backward	5	$z = -0.33$
Long term memory		
Doors test[b]		
Part A	10	*P*25
Part B	7	*P*25–*P*50
Total	17	*P*25
Executive functions		
Trail making test		
Part A		
Time	70 s	$z = -0.4$
Errors	0	
Part B		
Time	206 s	
Errors	(Interrupted at 7G)	
Luria's graphic series[c]	26.5	Normal
Visual processing		
B.O.R.B[d]		
Minimal feature view	25/25	$z = 0.85$
Batterie de décision d'objets[e]	70/72	CM = 68/72
Object/Non-Object decision[f]	71/72	CM = 68/72
Praxis[g]		
Visual recognition of gestures	57/60	–
Posture reproduction on a mannequin	9/10	–
Pantomiming the use of a pictured object	0/10	–
Use of familiar man-made objects	5/9	–
Delayed imitation		
Meaningless gestures		
Blocked condition	2/19	–
Mixed condition	0/20	–
Meaningful gestures		
Blocked condition	3/20	–
Mixed condition	0/20	–
Gesture production on verbal command	0/20	–

[a] Smirni, Villardita, and Zappala (1983).

[b] Baddeley, Emslie, and Nimmo-Smith (1994).

[c] Luria (1980).

[d] Riddoch and Humphreys (1993).

[e] Bergego et al. (2006).

[f] Samson et al. (1998).

[g] *Batterie d'Evaluation des Praxies*, Peigneux and Van der Linden (2000). This test took place in December 2007.

Table 2
Language examination of JJG (November–December 2007).

Tasks	JJG's score	JJG's z-score
Repetition[a]		
Words	17/18	n.a
Pseudo-words	1/6	n.a
Writing on dictation[a]		
Letter	4/8	n.a
Words	2/12	n.a
Pseudo-words	0/4	n.a
Oral spelling[a]		
Words	0/8	n.a
Pseudo-words	0/3	n.a
Reading aloud[a]		
Regular words	8/36	n.a
Irregular words	2/6	n.a
Pseudo-words	0/10	n.a
Spoken picture naming[b]	28/80	−21.7
Spoken word/picture matching[b]	70/80	−20.2

[a] *Batterie d'évaluation du langage* (Cliniques universitaires Saint-Luc, Brussels).
[b] de Partz, Bilocq, De Wilde, Seron, and Pillon (2001).

Language examination (see Table 2) was undertaken in November and December 2007. JJG's spontaneous speech was non-fluent, and was interspersed with frequent episodes of word-finding difficulties, in the context of correct articulation, prosody, and syntax. Repetition of phonemes, syllables, and words (both verbs and nouns) was preserved although repetition of pseudowords was impaired. There was also evidence for severe anomia, speech comprehension difficulties, and impaired reading and writing. Thus, JJG was severely impaired both in a picture naming and in a spoken word-to-picture matching task comprising the same set of concrete objects. His erroneous responses in naming were mainly non-responses and semantic paraphasias, and in matching, they mainly consisted in choosing the semantically related foil. This pattern suggested that JJG presented with a conceptual deficit.

Because difficulties in understanding verbs was noted in clinical settings, verb compared to noun processing was further assessed in JJG. The patient's performance was within the normal range in an auditory lexical decision task including nouns and verbs matched in spoken word frequency and pseudo-nouns and pseudo-verbs differing from real nouns and real verbs from one or two phonemes. The patient recognized most nouns (34/36) and rejected most pseudo-nouns (35/36); he also accepted all verbs (36/36) and rejected most pseudo-verbs (35/36). In a translated version of the "Kissing and Dancing Test" (KDT; Bak & Hodges, 2003) and the "Pyramid and Palm Trees test" (PPT; Howard & Patterson, 1992), which evaluate verb/action and noun/object processing, respectively, JJG was impaired with verbs/actions in both the spoken word (45/52; controls' mean = 51.8; SD = 0.45) and the picture (48/52; controls' mean = 52, SD = 0) version. He was also impaired with nouns/objects in both the spoken word (48/52; controls' mean = 51.8, SD = 0.45) and the picture (47/52; controls' mean = 51.8, SD = 0.45) version. No significant difference was observed between the picture and the word version either on the verbs/actions or the nouns/objects ($\chi^2 < 1$) or between verbs/actions and nouns/objects ($\chi^2 < 1$). We presented JJG with an additional association task similar to the KDT, which included 20 action items and in which the target response and the foil were selected so that they were matched in familiarity [t (38) < 1] and spoken word frequency [t (38) < 1]. JJG was again impaired both with the picture version (13/20) and the spoken word version (14/20), $\chi^2 < 1$, of this association task.

Given the sparing of spoken word, object, and gesture recognition processes in JJG (Cf. Supra), the results of the object and action association tasks suggested that JJG's difficulty in understanding verbs resulted from a conceptual deficit affecting action knowledge, and that he actually also presented with a conceptual deficit impairing object knowledge. The experimental study presented below was carried out in order to delineate more precisely and with a more controlled material the classes of concepts affected by the conceptual deficit and, then, to test different accounts for the pattern of co-occurrence of deficits for various classes of concepts within extant theories of conceptual organization.

3. Experimental study

3.1. General method

The experimental investigations were carried out from September 2007 to July 2009 in sessions lasting between 60 and 120 min. Unless otherwise indicated, the tasks were presented to the same group of 8 control subjects, matched with the patient for age (mean = 62.6; range = 60–64), gender, and years of education (mean = 16.2; range = 15–17).

Crawford and Howell's (1998) modified t-test was used to test whether the patient's performance on the various categories of items was significantly impaired in comparison to the control group's (test for the presence of a deficit). Crawford and Garthwaite's (2007) Bayesian Standardized Difference test (BSDT) was applied to test whether the discrepancy between two item categories in the patient's performance was significantly different from the discrepancy between them in 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 better protection against Type I errors when the size of the control group is small and, especially, when the patient's scores are extreme (z-score < −3.0), which was the case for JJG.

All the picture stimuli used in this study across the different batteries, unless otherwise indicated, were color photographs with no or minimal context presented in full-screen mode (15.4 in. screen) using PowerPoint software. The photographs of actions depicted all the persons, objects, and instruments typically involved in the action. The characteristics of these stimuli in terms of spoken word frequency, subjective word frequency, concept familiarity, imageability, and age of acquisition, are displayed in Table 3.

The general procedure used for the naming, word/picture matching, and word/picture verification tasks included in the different batteries presented to the participants was as follows:

- In the naming tasks, the participants were presented with all the items in one session and were asked to name them within 20 s. The naming of actions was elicited by the phrase *en train de* which requires being completed by the infinitive form of a verb ("*en train de* Verb$_{\text{inf}}$" is the French equivalent of English "Verb$_{\text{ing}}$").
- In the word/picture matching and the word/picture verification tasks, nouns were presented without their articles and verbs were presented in the infinitive form with the phrase *en train de*. In the word/picture matching tasks, each spoken word was presented simultaneously with an array of pictures (the correct picture and the semantic foils) in a balanced-order design and the participants were asked to point to the picture of the object or of the action that corresponded to the spoken word. In the word/picture verification tasks, each spoken word was presented once with the correct picture, and once with each of the foils, during the same session, and the participants were asked to tell whether the spoken word and the picture matched. An item was scored correct if, for that item, both the correct picture was accepted and each of the foils rejected. In both these tasks, there was no time limit set for the response, the photograph was displayed until the participant's response, and repetition of the word stimulus was allowed if necessary.

Table 3
Mean and standard deviation of the spoken word frequency, subjective word frequency, concept familiarity, imageability, and age of acquisition for the various subsets of items in the batteries used in the study.

	N	Spoken word frequency[a]	Subjective word frequency[b]	Familiarity[c]	Imageability[d]	Age of acquisition[e]
“Objects/Actions”						
Objects						
Living things	18	26.21 (34.19)	2.92 (0.72)	2.88 (0.75)	4.74 (0.18)	n.a.
Man-made objects	18	22.85 (33)	3.03 (0.58)	3.16 (0.68)	4.68 (0.28)	n.a.
Total objects	36	24.53 (33.16)	2.97 (0.65)	3.02 (0.72)	4.71 (0.23)	n.a.
Actions						
Object-directed actions	18	41.78 (49.74)	3.12 (0.61)	3.13 (0.65)	3.46 (0.44)	n.a.
Person-directed actions	18	41.74 (49.74)	3.10 (0.83)	3.16 (0.91)	3.46 (0.67)	n.a.
Total actions	36	41.76 (47.58)	3.11 (0.72)	3.14 (0.78)	3.46 (0.56)	n.a.
“Concrete Objects”						
Animals	25	10.19 (10.57)	2.53 (0.50)	2.69 (0.80)	4.39 (0.48)	2.46 (0.57)
Plants	25	6.66 (7.16)	2.77 (0.56)	2.83 (0.76)	4.48 (0.42)	2.54 (0.56)
Man-made objects	25	8.59 (8.89)	2.68 (0.76)	2.71 (0.92)	4.45 (0.38)	2.66 (0.59)
“Man-made Objects/Actions”						
Man-made objects	28	12.56 (15.30)	n.a.	3.02 (1.02)	4.20 (0.53)	2.62 (0.67)
Actions	28	14.34 (20.10)	n.a.	2.96 (0.85)	4.10 (0.51)	2.38 (0.58)
“Living things/Made-made Objects”						
Living things	32	9.44 (22.38)	2.60 (0.62)	n.a	4.45 (0.50)	n.a
Man-made objects	32	35.65 (87.20)	3.01 (0.91)	n.a	4.47 (0.34)	n.a
“Manipulable/Non-manipulable Items”						
Manipulable						
Man-made objects	16	5.63 (8.12)	n.a.	2.79 (0.64)	4.56 (0.56)	n.a.
Actions	16	23.98 (48.99)	n.a.	3.07 (0.49)	3.68 (0.51)	n.a.
Total manipulable	32	14.80 (35.78)	n.a.	2.93 (0.58)	4.12 (0.69)	n.a.
Non-manipulable						
Man-made objects	16	11.25 (16.80)	n.a.	3.01 (1.33)	4.62 (0.32)	n.a.
Actions	16	57.24 (70.27)	n.a.	3.34 (0.69)	3.82 (0.42)	n.a.
Total non-manipulable	32	34.24 (55.42)	n.a.	3.18 (1.05)	4.22 (0.55)	n.a.
Total man-made objects	32	8.44 (13.29)	n.a.	2.90 (1.03)	4.59 (0.45)	n.a.
Total actions	32	40.61 (61.94)	n.a.	3.20 (0.61)	3.75 (0.46)	n.a.
Manipulable/Non-manipulable Items of the “Man-made Objects/Actions” battery						
Manipulable items	30	13.62 (19.18)	n.a.	3.04 (1.04)	4.15 (0.46)	2.64 (0.65)
Non-manipulable items	26	13.26 (16.11)	n.a.	2.93 (0.81)	1.14 (0.58)	2.34 (0.58)

n.a. = non-available.

[a] Number of lemma occurrences per million in a corpus of subtitles of films (New, Brysbaert, Veronis, & Pallier, 2007).

[b] From Bonin, Boyer, Meot, Fayol, and Droit (2004) and Bonin, Meot et al. (2003) for the items of the “Concrete Objects” and the “Living Things/Man-made Objects” batteries; rated on a five-point scale (1 = low, 5 = high frequency) by 25 subjects for half of the items and 29 subjects for the second half (mean age = 66; SD = 8.9) for the items of the “Objects/Actions” battery.

[c] From Alario and Ferrand (1999), Bonin, Peereman, Malardier, Meot, and Chalard (2003), and Bonin et al. (2004) for the items of the “Concrete Objects”, “Living Things/Man-made Objects” and “Man-made Objects/Actions” batteries; rated on a five point scale (1 = low, 5 = high familiarity) by 20 subjects (mean age = 35.95; SD = 11.01) for the items of the “Manipulable/Non-manipulable Items” battery and by 27 subjects for half of the items and 26 subjects for the second half (mean age = 67; SD = 9.7) for the items of the “Objects/Actions” battery.

[d] From Bonin et al. (2004) and Bonin, Meot et al. (2003) for the items of the “Concrete Objects”, “Living Things/Man-made Objects” and “Man-made Objects/Actions” batteries; rated on a five point scale (1 = low, 5 = high imageability) by 20 subjects (mean age = 29.15; SD = 7.47) for the items of the “Manipulable/Non-manipulable Items” battery and by 27 subjects (mean age = 58.22) for the items of the “Objects/Actions” battery.

[e] From Alario and Ferrand (1999), Bonin, Peereman et al. (2003) and Bonin et al. (2004).

- Each task and session was preceded by a few examples designed to familiarize the participants with the task.

3.2. Delineating the scope of JJG’s conceptual impairment

3.2.1. Method and material

In order to delineate the classes of concepts that were impaired/spared by conceptual damage in JJG, four sets of tasks were presented to him and the control subjects: (1) a “Objects/Actions” battery assessing knowledge of objects and actions; (2) a “Concrete Objects” battery assessing knowledge of three categories of objects, i.e., animals, plants, man-made objects; (3) a “Man-made Objects/Actions” battery assessing knowledge of man-made objects compared to actions; (4) a “Unique Entities” battery assessing knowledge of famous people, countries, and famous buildings.

3.2.1.1. “Objects/Actions” battery. This battery was composed of a spoken picture naming and a spoken word/picture verification task. It contained 72 items, i.e., 36 objects and 36 actions. Among the 36 objects, half were living things, i.e., 9 animals and 9 plants, and half man-made objects, i.e., 9 tools and 9 other man-made objects. Among the 36 actions, half were “object-directed’ actions and half “person-directed” actions. “Object-directed actions” involved a man-made object either as the goal ($n = 9$; e.g., crushing) or as the instrument/tool ($n = 9$; e.g., hammering) of the action, while the “person-directed actions” included 9 whole-body actions (e.g., dancing) and 9 interactions (e.g., strangling). The object and the action set were matched for spoken-name frequency [$t\ (62) = -1.78$; $p = 0.08$], subjective frequency ($t < 1$), and concept familiarity ($t < 1$); however, the objects were more imageable than the actions [$t\ (47.1) = 12.34$; $p < 0.001$]. The living things and man-made objects, on the one hand, the object-directed and person-directed actions, on the other hand, were matched for spoken word frequency ($t < 1$), familiarity ($t < 1$), and imageability ($t < 1$). A color photograph with no or a minimal context was selected for each object and action and used in the naming task. 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. Filler items were added to increase the yes/no response ratio, which reached 0.34. Given the scoring procedure adopted (Cf. Section 3.1), the correct response probability at chance was 0.0625.

The same set of action items was further assessed in both naming and word/picture verification with videotaped stimuli instead of photographs in the naming and the word/picture verification task. Videotaped clips were prepared so that they resembled the corresponding photographs as closely as possible, with no additional information except from movement and duration. The participants were asked to wait until the end of each video clip before responding.

3.2.1.2. "Concrete Objects" battery. This battery was composed of a spoken picture naming, a word/picture matching, and a word/picture verification task including the same set of 75 items equally divided among the categories of animals ($n = 25$), plants ($n = 25$), and man-made objects ($n = 25$). The items from the three categories were matched in concept familiarity ($F < 1$), age of acquisition ($F < 1$), imageability ($F < 1$), subjective word frequency ($F < 1$), and objective spoken word frequency ($F < 1$). In the word/picture matching and the word/picture verification task, the foils were two semantic coordinates. These were selected on the basis of the ratings made by 30 subjects who were asked to evaluate on a 5-point scale the degree to which pairs of coordinates and targets presented as written words shared semantic characteristics (where 1 = no and 5 = a lot of characteristics in common). The foils did not differ in their mean semantic proximity with the targets across the three categories of items ($F < 1$). In the word/picture verification task, filler items were added to increase the yes/no response ratio, which reached 0.39. Given the scoring procedure (Cf. Section 3.1), the correct response probability at chance was 0.125.

3.2.1.3. "Man-made Objects/Actions" battery. This battery contained a spoken picture naming, a word/picture matching, and a word/picture verification task composed of the same set of 28 man-made objects (15 tools, e.g., a compass, and 13 non-tools, e.g., skirt, hammock, and bike) and actions (15 manual actions, e.g., drawing, and 13 non-manual actions, e.g., licking), matched for age of acquisition [t (54) = 1.42; $p = 0.16$], concept familiarity ($t < 1$), imageability ($t < 1$), and spoken word frequency ($t < 1$). Note also that the items of this battery were matched in familiarity ($F < 1$), spoken word frequency [F (4,126) = 1.35; $p = 0.25$] and age of acquisition ($F < 1$) with the items of the "Concrete objects" battery. In the word/picture matching and the word/picture verification task, the foils were two close semantic coordinates that were selected after an assessment of their semantic proximity with the targets, made by 33 control subjects who were asked to rate the degree to which pairs of concepts presented as written words shared common characteristics on a 5-point scale (1 = no to 5 = a lot of characteristics in common). No significant difference in mean semantic proximity between targets and foils was observed between the man-made object (mean = 3.35; SD = 0.72) and the action (mean = 3.08; SD = 0.77) sets [t (110) = 1.89; $p = 0.06$]. In the word/picture verification task, the yes/no response ratio reached 0.39 once filler items were added. With our scoring procedure, the correct response probability at chance was 0.125.

To assess the consistency of his performance, JJG was tested on the naming and the word/picture verification task three times in separate sessions over a six-month period.

3.2.1.4. "Unique Entities" battery. This battery was composed of three sets of tasks assessing knowledge of unique entities; the first set related to famous people, the second to countries, and the third to famous buildings. To assess knowledge of famous people, two tasks were prepared. In the first task, the participants were auditorily presented with the first name and surname of 60 famous people from different fields (sports, national and international politics, music, film or television) and had to point to the color photograph corresponding to the spoken name (e.g., *Johnny Depp*), among an array of five, i.e., the correct picture, a semantic foil (i.e., same profession, e.g., Ben Affleck), a visual foil (similar facial features, e.g., Stephan Eicher), a visuo-semantic foil (e.g., Vincent Pérez), and a phonological foil (similar name, e.g., Johnny Clegg). The second task was a binary choice task aimed at evaluating conceptual knowledge about 50 other famous people. Three properties of each famous person were assessed, namely, their profession, the country they were from, and a specific feature. In each trial, the name and surname of the famous person were auditorily presented with a phrase describing a correct property and a phrase describing an incorrect property (in a balanced order). Foils for the profession were in the same domain (e.g., Politician: Prime minister or President; Sport champion: Boxing or Cycling) and foils for the specific feature were a plausible coordinate (e.g., *Alfred Nobel invented the dynamite or the revolver?*). The participant had to tell which phrase was correct. One point was given for success on all three properties of a given person. Two tasks were also prepared to assess knowledge of countries. In the country pointing task, the participants were presented with four blank maps each depicting a continent (America, Europe, Asia, and Africa) and were asked to point successively toward the four auditorily presented continents, and then to six countries in America, Asia, and Africa and eight in Europe. In the second country task, the participants had to tell, among two choices, which was the capital, the specialty (both presented auditorily) or the flag (presented visually) of 20 countries worldwide. Foils for the capital were an important city of the same country (e.g., Switzerland: Bern or Geneva), foils for specialties were selected from the same category (e.g., Russia: Vodka or Whiskey), and foils for flags were chosen for their visual similarity (e.g., Greece: Greek or Uruguayan flag). One point was given for success on all three properties of a given country. Finally, knowledge of famous buildings was assessed through a binary choice task including 20 famous buildings. Three auditorily presented properties of each building, namely the country, the city, and name, were assessed on presentation of a color photograph of the building. For example, with the photograph of the *Sagrada Familia*, the examiner asked whether it was in Australia or Spain, whether it was located in Madrid or Barcelona, and whether it was named *La Casa Battlo* (another building from Gaudi) or *La Sagrada Familia*. One point was given if the three properties of a given building were all successfully identified.

3.2.2. Results

3.2.2.1. "Objects/Actions" battery. As shown in Table 4, JJG was significantly impaired in the naming and the word/picture verification task, but he was not differentially impaired for objects and actions in either task (BSDT: $p = 0.53$ and $p = 0.73$, in the naming and the verification task, respectively). JJG was also significantly impaired with the videotaped version of the naming and the word/picture verification task, with no significant difference between the videotaped and the photograph version in the naming task (BSDT: $p = 0.93$) but significantly *worse* performance in the videotaped compared to the photograph version in the verification task (BSDT: $p = 0.01$).

Within the object set, both living things and man-made objects were significantly impaired in naming, and there was no significant difference between both categories of objects (BSDT: $p = 0.75$). Likewise, within the action set, both person-directed and object-directed actions were significantly impaired, and there was no significant difference between both categories of actions (BSDT: $p = 0.28$). However, a different pattern of performance emerged in the verification task. Within the object set, JJG's performance was *not* significantly impaired for living things although it was significantly impaired for man-made objects. In fact, JJG's performance for man-made objects was significantly worse than his performance for living things (BSDT: $p < 0.005$). Then, it turned out that JJG's per-

Table 4
JJG's and control group's number of correct responses in the picture naming and the word/picture verification tasks for the items on the "Objects/Actions" battery, as well as in the video clip naming and verification tasks for the action items of the battery.

Task	*N*	JJG	Control subjects			Modified *t* test
			Mean	SD	Range	
Picture naming						
Objects						
Living things	18	9	17.87	0.35	17–18	-23.90^{***}
Man-made objects	18	6	17.62	0.51	17–18	-21.49^{***}
Total objects	36	15	35.50	0.75	34–36	-25.77^{***}
Actions						
Person-directed actions	18	5	16.37	1.06	15–18	-10.11^{***}
Object-directed actions	18	2	16.25	0.88	15–17	-15.26^{***}
Total actions	36	7	32.63	1.19	31–34	-20.47^{***}
Video clip naming						
Person-directed actions	18	3	17.37	0.51	17–18	-26.57^{***}
Object-directed actions	18	4	17.00	1.06	15–18	-11.56^{***}
Total actions	36	7	34.37	1.30	32–36	-19.85^{***}
Word/picture verification						
Objects						
Living things	18	16	17.50	0.75	16–18	−1.88
Man-made objects	18	14	17.87	0.35	17–18	-10.43^{***}
Total objects	36	30	35.37	0.74	34–36	-6.84^{***}
Actions						
Person-directed actions	18	7	16.37	1.59	14–18	-5.55^{***}
Object-directed actions	18	6	16.87	1.35	15–18	-7.59^{***}
Total actions	36	13	33.25	2.43	29–36	-7.95^{***}
Video clip verification						
Person-directed actions	18	5	17.65	0.51	17–18	-23.33^{***}
Object-directed actions	18	6	17.75	0.70	16–18	-15.82^{***}
Total actions	36	11	35.37	1.06	33–36	-21.68^{***}

*** $p < 0.001$.

formance for man-made objects did not significantly differ from his performance for actions (BSDT: $p = 0.36$), while his performance for living things significantly differed from his performance for actions (BSDT: $p < 0.02$). Within the action set, no significant difference was found between person-directed and object-directed actions either in the photograph (BSDT: $p = 0.42$) or in the videotaped (BSDT: $p = 0.23$) version.

3.2.2.2. "Concrete Objects" battery. The results are displayed in Table 5. In naming, JJG's performance was significantly impaired for the three categories of objects, but it was significantly more impaired for man-made objects than for both animals (BSDT: $p < 0.01$) and plants (BSDT: $p < 0.01$) which themselves were not differentially impaired (BSDT: $p = 0.54$). In the word/picture matching task, JJG's performance was not significantly different from controls for animals and plants but was significantly impaired for man-made objects. His performance was significantly poorer for man-made objects than for both animals (BSDT: $p < 0.01$) and plants (BSDT: $p < 0.01$) and it was not significantly different between animals and plants (BSDT: $p = 0.18$). Likewise, in the word/picture verification task, JJG's performance did not differ from controls for animals and plants but was significantly impaired for man-made objects. Once again, his performance was significantly poorer for man-made objects than for both animals (BSDT: $p < 0.01$) and plants (BSDT: $p = 0.01$), and there was no significant difference in his performance between animals and plants (BSDT: $p = 0.98$).

3.2.2.3. "Man-made Objects/Actions" battery. The results are displayed in Table 6. In picture naming, JJG's performance was significantly impaired relative to the control group in all three sessions and for both man-made objects and actions. There was no significant difference between his impairment for man-made objects and for actions in any of the three sessions (all BSDTs: $p > 0.58$). In the word/picture matching task, JJG's performance was significantly and similarly impaired for man-made objects and actions (BSDT: $p = 0.69$). In the word/picture verification task, JJG's performance was again significantly impaired for both man-made objects and actions in all three sessions, with none of the differences between these two categories being significant (all BSDTs: $p > 0.35$). When the scores from the three sessions were averaged, JJG's performance still did not show any significant difference between man-made objects and actions, either in naming (BSDT: $p > 0.75$) or in the word/picture verification task (BSDT: $p > 0.87$).

3.2.2.4. Distribution of JJG's errors. Whatever the battery ("Objects/Actions", "Concrete Objects", or "Man-made Objects/Actions" battery) and the category of items (living things, man-made objects, or actions), JJG's errors in naming mainly consisted in non-responses or unrelated words, followed by semantic paraphasias; in the word/picture verification tasks, his errors most often consisted in accepting a semantic foil (see Appendix for detailed results). In the word/picture matching tasks, the only possible type of error was pointing to a semantic foil.

3.2.2.5. Additional analyses of the "Man-made Objects vs. Actions" contrast. We performed an analysis with all the man-made object and action items from the previous batteries.[3] In that way, the set of man-made objects amounted to 71 (18 + 25 + 28) and the set of actions to 64 (36 + 28). JJG's and the control's performance for this item set is displayed in Table 7. The results showed again a not significantly different impairment for man-made objects and actions in the naming (BSDT: $p = 0.18$) or the verification task (BSDT: $p = 0.78$). If we again increased the number of items by adding to the previous set, the set of 32 man-made objects and 32 actions from the "Manipulable/Non-manipulable Items" battery that will be presented in the next section (Cf. Infra), thereby obtaining a set of 103 man-made objects and 96 actions (see Table 7 for JJG's and

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[3] In these additional analyses, the naming data for the action items from the "Objects/Actions" battery were those of the naming from photographs and the data from the "Man-made Objects/Actions" battery were those of the first presentation.

Table 5
JJG's and control group's number of correct responses in the picture naming, word/picture matching, and word/picture verification task of the "Concrete Objects" battery.

Task	N	JJG	Control subjects			Modified t test
			Mean	SD	Range	
Naming						
Animals	25	7	23.13	1.55	20–25	−9.20***
Plants	25	5	23.00	1.41	21–25	−12.03***
Man-made objects	25	7	24.00	0.53	23–25	−30.24***
Word/picture matching						
Animals	25	25	24.62	0.38	23–25	0.90
Plants	25	24	24.62	0.76	23–25	−0.79
Man-made objects	25	17	24.75	0.38	24–25	−19.74***
Word/picture verification						
Animals	25	19	20.87	2.64	16–23	−0.67
Plants	25	20	21.12	1.80	19–24	−0.59
Man-made objects	25	7	21.00	1.85	19–25	−7.13***

*** $p < 0.001$.

Table 6
JJG's and control group's number of correct responses in picture naming, word/picture matching, and word/picture verification for the "Man-made Objects/Actions" battery and at the three sessions of testing.

Task	Items	N	JJG	Control group			Modified t test
				Mean	SD	Range	
Naming							
Session 1	Man-made objects	28	11	26.50	0.93	25–27	−15.88***
	Actions	28	6	26.00	1.19	24–28	−15.85***
Session 2	Man-made objects	28	14	26.50	0.93	25–27	−12.81***
	Actions	28	7	26.00	1.19	24–28	−15.05***
Session 3	Man-made objects	28	15	26.50	0.93	25–27	−11.79***
	Actions	28	8	26.00	1.19	24–28	−14.26***
Word/picture matching	Man-made objects	28	21	27.75	0.46	27–28	−13.83***
	Actions	28	19	27.12	0.64	26–28	−11.97***
Word/picture verification							
Session 1	Man-made objects	28	8	26.75	1.28	25–28	−13.81***
	Actions	28	5	25.50	1.41	24–28	−13.71***
Session 2	Man-made objects	28	12	26.75	1.28	25–28	−10.86***
	Actions	28	7	25.50	1.41	24–28	−12.37***
Session 3	Man-made objects	28	8	26.75	1.28	25–28	−13.81***
	Actions	28	9	25.50	1.41	24–28	−11.03***

*** $p < 0.001$.

the control's performance for this set), still no significant difference was found between the impairment for man-made objects and actions in the naming task (BSDT: $p = 0.24$) or the word/picture verification task (BSDT: $p = 0.38$).

3.2.2.6. "Unique Entities" battery. In the famous people tasks, JJG scored 51/60 (controls: 42–59, mean = 50.7, SD = 6.50) when he had to point to the picture of a named person, which was an unimpaired performance (modified $t < 1$), and he scored 35/50 (controls: 33–46, mean = 39.6, SD = 4.30) when he had to retrieve semantic properties about famous people, again an unimpaired performance [modified $t\,(7) = -1$, $p = 0.18$]. When asked to identify continents and locate countries on maps, JJG scored 27/30, which was within the control subjects' range of performance (27–30, mean = 28.1, SD = 1) and indicated no significant deficit [modified $t\,(7) = -1.03$, $p = 0.17$]. He also identified accurately all the three features of the countries for 17/20 countries, which was again within the control group's range of performance (15–20, mean = 17, SD = 2), and not significantly impaired (modified $t < 1$). Finally, in accessing the semantic properties of the famous buildings, JJG scored 16/20 (controls: 15–19, mean = 17.5, SD = 1.69), which was not significantly different from the control group (modified $t < 1$).

Table 7
JJG's and control group's number of correct responses in picture naming and word/picture verification for the two sets of man-made object and action items combined from the different batteries.

Task	N	JJG	Control group			Modified t test
			Mean	SD	Range	
Naming						
Man-made objects	71	24	68.12	1.12	66–69	−37.01***
Actions	64	13	58.60	1.68	57–62	−25.60***
Man-made objects	103	41	96.37	2.44	92–100	−21.34***
Actions	96	19	85.75	1.90	82–88	−33.12***
Word/picture verification						
Man-made objects	71	30	65.62	2.92	61–71	−11.50***
Actions	64	18	58.75	3.10	53–63	−12.39***
Man-made objects	103	53	95.37	3.20	91–102	−11.89***
Actions	96	38	89.25	2.96	84–92	−16.32***

*** $p < 0.001$.

3.2.3. Discussion

The results of this first set of tasks first indicated that JJG presented with a conceptual impairment that *selectively* and severely affected his knowledge of man-made objects and of actions although his naming performance suggested that he probably presented with an additional deficit in retrieving the phonological word forms, which affected his performance and caused similar naming errors in all classes of words. Thus, with the three different sets of items including man-made objects (“Objects/Actions”, “Concrete Objects”, and “Man-made Objects/Actions” batteries), the results showed that JJG was significantly impaired in the comprehension tasks (word/picture matching or word/picture verification tasks) with man-made objects. Furthermore, in these comprehension tasks and in the two different sets of items where both living things and man-made objects were present (“Objects/Actions” and “Concrete Objects” batteries), his performance with man-made objects appeared disproportionately impaired compared to his performance with living things, both animals and plants that, in fact, were spared. Likewise, in both the item sets including action items (“Objects/Actions” and “Man-made Objects/Actions” batteries), JJG’s knowledge of actions appeared significantly impaired. A summary of the results obtained in the comprehension tasks (word/picture verification) with the living thing, man-made object, and action items from the various item sets, together with the results obtained in the tasks assessing knowledge of unique entities, is displayed in Fig. 2.

Two interpretations of the pattern of association of a deficit for man-made objects and for actions already can be ruled out on the basis of the results of this set of tasks. First, the associated conceptual impairment for both man-made objects and actions cannot be explained simply by an across-the-board conceptual deficit with a selective *preservation* of living things, say, as a preservation of knowledge sustained by specialized domain-specific processing systems (Caramazza & Shelton, 1998). Knowledge of other classes of entities was indeed preserved in JJG, that is, unique entities like countries and famous buildings (the preservation of famous people knowledge was also preserved, but this could be explained, within the domain-specific knowledge framework, as a preservation of a specialized system for representing conspecifics). Second, the associated conceptual impairment for both man-made objects and actions cannot be explained either by the processing of actions being impaired because of a deficit in accessing knowledge of the man-made objects that are involved in the actions. Like the results of the “Object/Actions” battery showed, actions that involve man-made objects (“object-directed” actions) were no more impaired than actions that do not involve man-made objects (“person-directed” actions).

Now the question is whether JJG’s pattern of conceptual impairment should be considered as a mere co-occurrence of deficits resulting from two independently damaged functional components within the conceptual system or rather as a theoretically relevant association of deficits due to the selective impairment of a single component involved in the conceptual processing of both man-made objects and actions. Although the two independent component account cannot be formally ruled out, we believe that JJG’s pattern of conceptual impairment presented several features that are more naturally accounted for within a single component hypothesis. First, the deficits JJG presented for both man-made objects and actions presented a specific feature that was absent in most associations of deficits reported on or discussed in the neuropsychological literature (e.g., Gerstmann, 1940; Warrington & McCarthy, 1987; Warrington & Shallice, 1984): both deficits were of a similar degree of severity. Both in the “Objects/Actions” battery and in the “Man-made Objects/Actions” battery, we found no evidence for JJG’s impairment being of a different degree of severity for man-made objects and actions. Second, this pattern of similar severity was found with two different samples of items (“Objects/Actions” and “Man-made Objects/Actions”) and, third, it was found consistently across three examinations during a six-month period. Again, none of these facts provides compelling evidence to reject a two independent component account for the association of deficits in JJG. However, taken together, they strongly suggest a more parsimonious account in terms of a single component deficit.

We may add that the same outcome was found when we gathered the data from all the action and man-made object items from the various batteries used in this study, which increased statistical power. Thus, the consistently negative result of the man-made objects *vs.* actions contrasts obtained in each set was unlikely due to a lack of statistical power or a sample bias. Therefore, in the following section, we tested several hypotheses that could account for the association of deficits in JJG’s pattern of conceptual impairment by assuming damage to a single functional component.

3.3. Assessing knowledge of sensory, functional, and manipulation features

Within both the Feature-Based Organization and the motor simulation theories, the association of a conceptual deficit for man-made objects and for actions could be accounted for by both classes of concepts being mainly (albeit not solely) represented and processed by a shared system which would be selectively damaged in the case of JJG. This shared system would be a conceptual system representing functional knowledge, within the “sensory/functional” account (Bird et al., 2000),[4] or manipulation knowledge within the “manipulability” account (e.g., Gerlach et al., 2002; Kellenbach et al., 2003; Noppeney et al., 2005; Saccuman et al., 2006), or a motor system involved in hand/arm movement simulations, within the “failure-of-simulating” account (e.g., Gallese & Lakoff, 2005; Rizzolatti & Craighero, 2004; Rizzolatti et al., 2001).

Let us remind here that the “sensory/functional” account predicts that a selective conceptual deficit for man-made objects and actions should be associated with a selective or disproportionate deficit for functional compared to sensory knowledge in all categories of concepts (i.e., living things, man-made objects, and actions). The “manipulability” account instead predicts that a selective conceptual deficit for man-made objects and actions should be associated with a selective or disproportionate impairment of manipulation compared to other kinds of knowledge, say, functional knowledge, and that manipulable objects and manipulation actions should be more impaired than non-manipulable objects and non-manipulation actions. As for the “failure-of-simulating” account, it predicts that a selective conceptual deficit for man-made objects and actions should be selective or disproportionate for manipulable objects and manual actions compared to non-manipulable objects and non-manual (i.e., whole-body) actions.

3.3.1. Materials and method

3.3.1.1. Sensory vs. functional features of objects and actions. Sensory and functional features were assessed with a property verification task (Pillon and d’Honincthun, submitted for publication-b) comprising the object and action items of the “Objects/Actions” battery. Four statements were associated with each item. Two statements (one true, one false) expressed a sensory property, and two state-

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[4] Already, the absence of evidence for a differential impairment for man-made objects and actions in JJG is problematic for the sensory-functional theory. However, it could be objected that, in the sets of items used previously, the actions had fewer functional features than average and/or the man-made objects had more functional features than average, leading to a similar impairment of both categories.

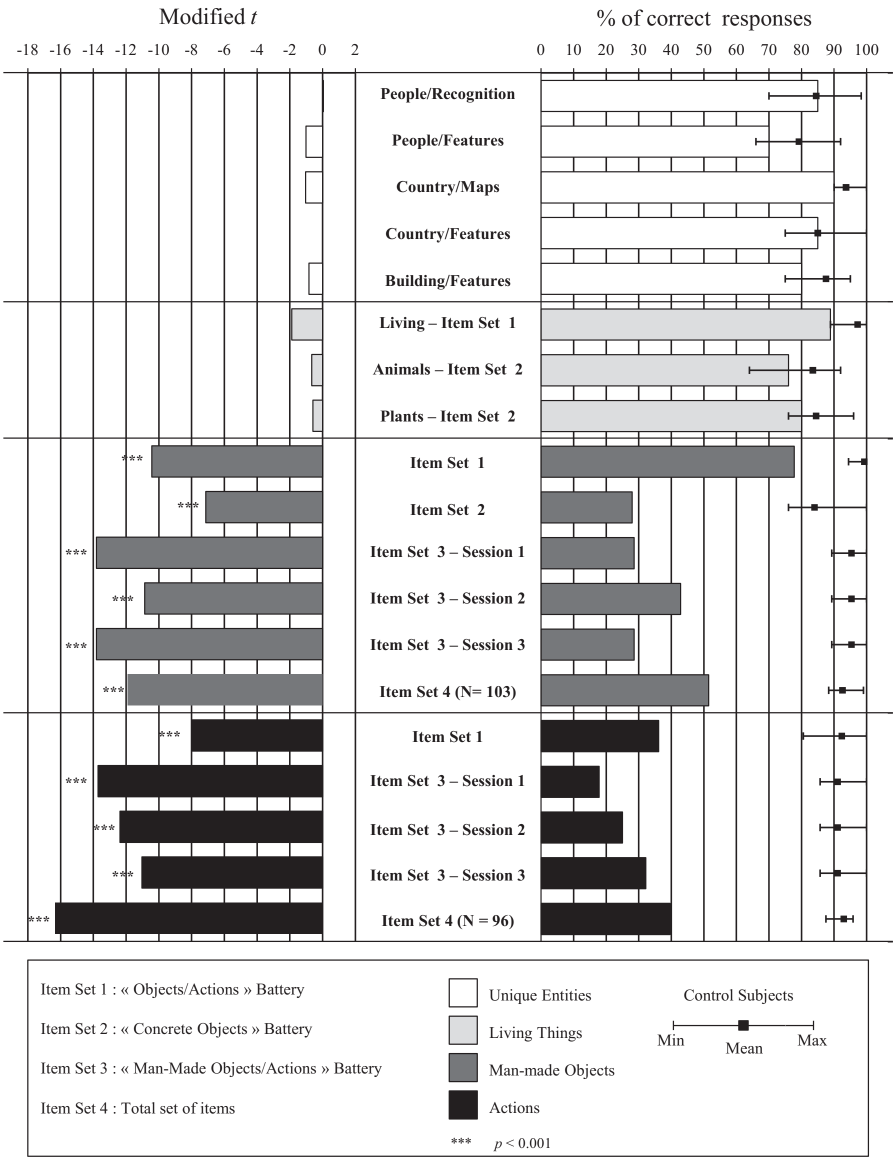

Fig. 2. Summary of JJG's and control subjects' results in the word/picture verification task with the living thing, man-made object, and action items from the various item sets ("Objects/Actions", "Concrete Objects", "Man-made Objects/Actions" batteries, and total item set), and in the tasks assessing knowledge of unique entities. On the right, the figure displays the percentage of JJG's correct responses with the mean percentage and range (min–max) of correct responses of the control subjects and, on the left, the results of the modified *t*-tests for the comparison between JJG's and control subjects' performance.

ments (one true, one false) expressed a functional property of the item. The sensory *vs.* functional properties were defined, following Bird et al. (2000), as knowledge that can *vs.* cannot be derived from the senses ("functional" thus refers to all "non-sensory" information). Thus, for objects, sensory properties mainly referred to the visual properties of objects (their shape, parts, color, or material), but also to features such as the taste of fruit and the feel of a plant; functional properties were eating habits, living environments, or utilization (e.g., transportation or rearing) for animals, growing environments or modes of cooking for fruit and vegetables, function for implements and, for means of transport, what is transported or the specific place where it is used. For actions, sensory properties described the typical visual motion associated with the action and functional properties described the cause, goal, or result of the action. Each statement was spoken aloud to the participants who had to tell whether it was true or false. A sensory or functional property of an item was scored correct if, for that given property, both the true statement was accepted and the false statement rejected. An item was scored correct overall if both the functional and sensory statements related to that item were succeeded.

For this task, the control group was the group of five healthy participants from the study by Pillon and d'Honincthun (submitted for publication-b). These participants were a bit younger than JJG (mean age = 43.2; SD = 2.28) but matched with him for gender and education level (mean number of years = 16.4; SD = 0.89).

3.3.1.2. Sensory vs. functional features of living things and man-made objects. A further property verification task was prepared with 64 items corresponding to concrete objects (hereafter, "Living Things/Man-made Objects" battery), half living things (16 animals and 16 fruit and vegetables), and half man-made objects (16 implements and 16 means of transport), matched for spoken word frequency [t (35) = 1.65, p = 0.1] and imageability (t < 1). Each item was associated with two statements (one true, one false) describing a sensory property and two statements (one true, one false) describing a functional property. Sensory and functional properties were

Table 8
Control subjects' mean ratings of difficulty of responding to the sensory and functional features in the property verification task for the items of the "Living Things/Man-made Objects" battery.

Category of items	N	Mean difficulty	SD
Sensory features			
Living things	32	1.69	0.57
Man-made objects	32	1.95	0.71
All sensory features	64	1.82	0.65
Functional features			
Living things	32	2.12	0.47
Man-made objects	32	1.61	0.50
All functional features	64	1.86	0.55
Living things	32	2.00	0.36
Man-made objects	32	1.89	0.49

defined as above. (These items and the corresponding statements were a subset of those used by Samson et al., 1998.) The statements were submitted to 9 control subjects (aged between 19 and 27) who were asked to verify the properties and to rate on a five-point scale how easy each was to answer (1 = very easy; 5 = very difficult). The mean difficulty of the statements did not differ between living things and man-made objects [$t\,(62) = 1.04$, $p = 0.3$] or between sensory and functional properties ($t < 1$). (See the mean ratings per category in Table 8.) The instructions and the scoring procedure were the same as in the previous property verification task.

3.3.1.3. Manipulation vs. functional knowledge. A picture association task was prepared with 50 pictures of manipulable man-made objects that, in one condition, the participants had to associate with an object that is manipulated in a similar way (manipulation condition) and, in a second condition, with an object that had a similar function (functional condition). The two conditions were presented in an ABBA order: in the first session, the participants were presented with the first half of the items in the functional condition and the second half of the items in the manipulation condition; in the second session, they were tested with the second half of items in the functional condition and the first half of the manipulation items. The same material was used in both conditions, that is, the same test items and the same array of choices were displayed in the same order in both the functional and the manipulation conditions. This allowed us to match perfectly the material used in both conditions. Thus, in both the functional and the manipulation conditions, the test item (e.g., a cigarette lighter) was presented with, below it, a picture of an object having a similar function (e.g., a match), a picture of an object that is manipulated in a similar way (e.g., a chronometer), and a visually related object (e.g., a salt shaker). In order to prevent the participants to discard the picture s/he previously chosen in the first presentation of the test item when presented with that item the second time, the same picture served as the correct associate for both the functional and the manipulation conditions in 28% of the trials; in these trials, the two other choices were visually related objects (e.g., the test item was a tiller, the functional and manipulation associate was a steering wheel and the two visually related objects were a ring and a lifebuoy). The test objects, their functional and manipulation associates, and the visually related objects were matched in imageability ($F < 1$), age of acquisition ($F < 1$), familiarity ($F < 1$), and subjective word frequency ($F < 1$).

3.3.1.4. "Manipulable vs. Non-manipulable Items" battery. This battery comprised a picture naming and a word/picture verification task including 32 manipulable (16 man-made objects and 16 actions) and 32 non-manipulable (16 man-made objects and 16 actions) items. Manipulability was estimated by three independent judges who were asked to tell whether 60 man-made objects and 60 actions entailed manipulation, i.e., whether the utilization of the object or the realization of the action entailed specific and fine hand motion (Saccuman et al., 2006).[5] Only items that reached 100% agreement across the judges were selected. Manipulable and non-manipulable items were matched in spoken word frequency [$t\,(62) = 1.67$; $p = 0.10$], concept familiarity [$t\,(62) = 1.15$; $p = 0.25$], and imageability ($t < 1$). Within the set of man-made objects, the 16 manipulable and 16 non-manipulable items were also matched in familiarity [$t\,(21.7) = -0.60$; $p = 0.55$], imageability [$t\,(30) = -0.39$; $p = 0.70$], and spoken word frequency [$t\,(30) = -1.20$; $p = 0.24$]. The same was true within the set of actions ($0.86 < t < 1.55$; $0.13 < p < 0.40$). In the word/picture verification task, one semantic and one unrelated foil were selected. The yes/no response ratio reached 0.4 once the filler items were added. With our scoring procedure (Cf. Section 3.1), the correct response probability at chance was 0.125.

3.3.1.5. "Manipulable vs. Non-manipulable Items" of the "Man-made Objects/Actions" battery. We applied the same analysis to the items of the "Man-made objects/Actions" battery, by splitting the set of items into manipulable (15 man-made objects and 15 actions) and non-manipulable (13 man-made object and 13 actions) items, according to the same criteria as those applied in the previously presented task. The manipulable and non-manipulable items were matched in spoken word frequency ($t < 1$), familiarity ($t < 1$), age of acquisition [$t\,(54) = 1.79$; $p = 0.08$], and imageability ($t < 1$). These variables were also matched between manipulable and non-manipulable man-made objects (all ts < 1.44; all ps > 0.16) and between manipulable and non-manipulable actions (all ts < 1.95; all ps > 0.06).

3.3.2. Results

3.3.2.1. Sensory vs. functional features of objects and actions. In the property verification task (see results in Table 9), JJG's overall performance was significantly impaired for both objects and actions and there was no significant difference between objects and actions (BSDT: $p = 0.37$). Like in the word/picture verification task with the same items, JJG's performance was however less impaired for living things than for man-made objects within the object set[6] and it did not significantly differ between man-made objects and actions (BSDT: $p = 0.52$) while it differed between living things and actions (BSDT: $p = 0.01$). As regards the sensory/functional contrast, the results showed that JJG was significantly impaired for both sensory and functional properties, with no evidence of a differential impairment between both kinds of properties, either for the whole set of items (BSDT: $p = 0.21$), for objects (BSDT: $p = 0.82$), or for actions (BSDT: $p = 0.87$).

3.3.2.2. Sensory vs. functional features of living things and made-made objects. The overall results (see Table 9) showed that, in this property verification task, JJG performed within the normal range for living things but was significantly impaired for man-made objects and that his performance was significantly poorer for man-made objects than for living things (BSDT: $p < 0.01$). Moreover, his performance was significantly worse for the sensory than the functional properties, on the whole (BSDT: $p = 0.02$) and for the

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[5] They were provided with 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. Non-manipulable 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). Non-manipulation 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)".

[6] See the modified ts values in Table 8. BSDT could not be computed because the SD in controls was nil.

Table 9

JJG's and control group's number of correct responses according to the type of feature and the category of items in the property verification tasks with the items of the "Objects/Actions" battery and of the "Living Things/Man-made Objects" battery.

Task	*N*	JJG	Control group			Modified *t* test
			Mean	SD	Range	
"Objects/Actions" battery						
Sensory features						
Living things	18	12	17.00	0.71	32–36	−6.42[**]
Man-made objects	18	5	17.20	0.84	16–18	−13.25[***]
All objects	36	17	34.40	1.51	32–36	−10.52[***]
Person-directed actions	18	5	16.20	1.48	14–18	−6.90[**]
Object-directed actions	18	2	16.80	0.45	16–17	−30.02[***]
All actions	36	7	33.00	1.41	31–35	−16.83[***]
All sensory features	72	23	64.70	1.82	65–70	−20.92[***]
Functional features						
Living things	18	13	16.80	0.84	16–18	−4.12[**]
Man-made objects	18	8	15.60	0.55	15–16	−12.61[***]
All objects	36	21	32.40	0.89	31–33	−11.69[***]
Person-directed actions	18	5	15.20	0.84	14–16	−11.08[***]
Object-directed actions	18	3	15.40	0.89	14–16	−12.71[***]
All actions	36	8	30.60	1.14	29–32	−18.09[***]
All functional features	72	29	63.00	1.00	62–64	−31.03[***]
All features						
Living things	18	11	16.00	0.70	15–17	−6.52[**]
Man-made objects	18	2	15.20	0.83	14–16	−14.50[***]
All objects	36	13	31.20	1.09	30–33	−15.24[***]
Person-directed actions	18	0	14.60	0.55	14–15	−25.18[***]
Object-directed actions	18	2	14.60	1.52	12–16	−7.86[***]
All actions	36	2	29.20	1.30	27–30	−19.10[***]
"Living things/Man-made Objects" battery						
Sensory features						
Living things	32	27	27.89	1.17	26–30	−0.72
Man-made objects	32	14	28.44	1.74	25–31	−7.87[***]
All sensory features	64	41	56.33	2.17	53–59	−6.70[***]
Functional features						
Living things	32	28	29.33	1.58	27–31	−0.79
Man-made objects	32	26	30.89	1.27	28–32	−3.67[**]
All functional features	64	54	60.22	2.22	57–63	−2.65[*]
All features						
Living things	32	23	25.78	1.79	23–29	−1.48
Man-made objects	32	13	27.78	2.59	22–31	−5.43[***]

[*] $p < 0.05$.
[**] $p < 0.01$.
[***] $p < 0.001$.

Table 10

JJG's and control group's number of correct responses according to the type of feature and the category of items in the property verification tasks with the items of the "Objects/Actions" battery and of the "Living Things/Man-made Objects" battery, with a strict definition of the functional features.

Task	*N*	JJG	Control group			Modified *t* test
			Mean	SD	Range	
"Objects/Actions" battery						
Sensory features						
Man-made objects	12	3	11.20	0.84	10–12	−9.81[***]
Person-directed actions	10	3	9.60	0.55	9–10	−11.17[***]
Object-directed actions	17	2	15.80	0.44	15–16	−28.63[***]
All actions	27	5	25.40	0.55	25–26	−34.36[***]
All sensory features	39	8	36.60	1.14	35–38	−22.90[***]
Functional features						
Man-made objects	12	4	10.40	0.89	9–11	−7.15[**]
Person-directed actions	10	4	8.60	1.14	7–10	−3.68[*]
Object-directed actions	17	2	14.20	1.30	12–15	−8.57[***]
All Actions	27	6	22.80	1.64	21–25	−9.35[***]
All functional features	39	10	33.20	1.30	32–35	−16.29[***]
All features						
Man-made objects	12	1	10.00	1.00	9–11	−8.22[***]
Person-directed actions	10	1	8.40	0.89	7–9	−7.59[***]
Object-directed actions	17	1	13.60	1.51	11–15	−7.62[***]
All actions	27	2	22.00	1.22	20–23	−14.96[***]
"Living things/Man-made Objects" battery						
Sensory features						
Man-made objects	24	10	21.00	1.32	19–23	−7.91[***]
Functional features						
Man-made objects	24	20	23.11	0.92	21–24	−3.18[**]

[*] $p < 0.05$.
[**] $p < 0.01$.
[***] $p < 0.001$.

man-made objects (BSDT: $p = 0.005$), but not for the living things (BSDT: $p = 0.95$). Thus, contrary to what the sensory/functional account for a category-specific deficit for man-made objects predicts, JJG performed better on the functional than on the visual properties of man-made objects.

3.3.2.3. Supplementary analyses: Sensory vs. "strictly functional" features. Functional knowledge related to objects has been characterized in different ways (e.g., Caramazza & Shelton, 1998; Cree & McRae, 2003; Farah & McClelland, 1991; McRae, de Sa, & Seidenberg, 1997). In our two property verification tasks, following Bird et al.'s conception, the functional statements associated with the object items expressed their "functional" properties in the broad sense of "non-sensory" properties, which encompasses the function of an object (e.g., *The kettle is used for heating water*) but also its typical location (e.g., *The pouffe usually stands in a lounge*), its utilization (e.g., *Cows are reared for milk*) and associative and encyclopaedic knowledge (e.g., *Foxes chase hens*). Likewise, the functional statements associated with the action items expressed various properties that were not strictly related to the "function", i.e., the purpose of the action (e.g., *Grating something is for reducing it into powder or small pieces* or *stretching is for relaxing*), but also to its cause (e.g., *When one pushes somebody away, it is because this person bothers him/her*) or consequence (e.g., *When one pinches somebody, this hurts him/her a bit*). One might object that the kind of features that the most crucially distinguishes living things from man-made objects and actions are not functional features defined in this broad sense, but "strictly" functional features, namely, properties pertaining to the *function* of the objects and the purpose of the actions – in other words, "what for" information. To address this issue, we re-analyzed the results of both property verification tasks by only keeping the items for which both the true and the false functional statement corresponded to this narrower definition. The results are displayed in Table 10.

In the property verification task with the items from the "Objects/Actions" battery, 12 man-made objects and 27 actions (10 person-directed and 17 object-directed) could be kept in the analysis (no statement related to living things conformed to the strict definition of function). The overall results showed that JJG was significantly impaired for both man-made objects and actions and that there was no evidence for a differential impairment between both categories (BSDT: $p = 0.18$). As for the sensory/functional contrast, the results showed that JJG was significantly impaired for both the sensory and functional properties; moreover, there was no evidence of a differential impairment between both kinds of properties, either in the whole set of items (BSDT: $p = 0.46$) or in the man-made object set (BSDT: $p = 0.47$). Only for the action set was there a significant difference in JJG's performance for sensory compared to functional features, which went however in the reverse direction of that predicted by the sensory/functional account: JJG was significantly *less* impaired for the functional compared to the sensory properties of actions (BSDT: $p < 0.02$).

In the property verification task with the items of the "Living things/Man-made Objects" battery, 24 man-made object items (no living things) remained once only functional statements conforming to the strict definition were kept. The results showed that JJG was significantly impaired for both the sensory and functional properties of man-made objects and that he was significantly *less* impaired for the functional compared to the sensory properties of these objects (BSDT: $p < 0.02$) – a pattern that is, again, the reverse of that predicted by the sensory/functional account for the category-specific deficit for man-made objects.

3.3.2.4. Manipulation vs. functional knowledge. The results indicated that JJG was significantly impaired both in the manipulation [20/50; controls' mean = 46.1, SD = 1.95; modified t (7) = −12.63, $p < 0.01$] and in the functional [26/50; controls' mean = 46.87; SD = 2.41; t (7) = −8.16. $p < 0.01$] condition and that there was no significant difference between both conditions (BSDT: $p = 0.19$).

3.3.2.5. "Manipulable vs. Non-manipulable Items" battery. The results (Table 11) showed that JJG was not differently impaired for manipulable and non-manipulable items both in the naming and the word/picture verification task, whether for man-made objects (BSDT: $p = 0.26$ and $p = 0.39$, in the naming and verification task, respectively), actions (BSDT: $p = 0.09$ and $p = 0.15$), or the whole set (BSDT: $p = 0.79$ and $p = 0.76$). For actions, the non significant trend was toward better performance for actions involving a manipulation than actions non involving manipulation, in both naming and word/picture verification.

3.3.2.6. Manipulable vs. Non-manipulable Items from the "Man-made Objects/Actions" battery. The results (Table 11) showed that there were no significant differences between manipulable and non-manipulable items across the three sessions on either the naming (BSDTs: $0.18 < p < 0.33$), the word/picture matching (BSDT: $p = 0.45$), or the word/picture verification (BSDTs: $0.43 < p < 0.73$) tasks.

3.3.3. Discussion

The main findings of this section are summarized in Fig. 3. They are clear-cut: JJG's conceptual impairment for both man-made objects and actions was not associated with a greater impairment of functional compared to sensory knowledge or to a greater impairment of manipulation compared to functional knowledge. Furthermore, manipulable items were not more impaired than non-manipulable items. These findings thus provided no support for the "sensory/functional", the "manipulability", or the "failure-of-simulating" account for the pattern of association of conceptual deficits found in JJG. Moreover, we found additional evidence that knowledge of man-made objects and actions was similarly affected by brain damage in a task where knowledge of the properties of items was directly assessed, i.e., the property verification task, which showed that the JJG's difficulties were not confined to naming or comprehending words from these semantic categories but indeed reflected impaired conceptual knowledge of man-made objects and of actions.

4. General discussion

4.1. Main findings

We have reported the case of a brain-damaged individual, JJG, who was referred to us because of his difficulties in understanding verbs. We found that his impairment with verbs was likely due to a conceptual impairment affecting action concepts although there was no significant dissociation in the patient's performance between verbs/actions and nouns/objects, when the nouns/objects set comprised both living and non-living (i.e., man-made objects) things. We then found that the patient's performance in comprehension tasks (word/picture matching and word/picture verification) presented in fact a classical dissociation within the set of objects, with a significant impairment for the category of man-made objects and a sparing of the category of living things. Knowledge related to other categories of entities, like famous people, countries, and famous buildings, was also spared, which indicated that the selective impairment for man-made objects could not be interpreted, like for example within the domain-specific knowledge theory (Caramazza & Shelton, 1998), as a selective preservation of living things. Finally, it turned out that the concepts of actions and of man-made objects were both impaired to a similar degree and that this pattern did not simply result from many actions involving man-made objects, since both actions involving and not involving man-made objects were impaired (and they were

Table 11
JJG's and control group's number of correct responses in picture naming and word/picture verification for the items of the "Manipulable/Non-manipulable Items" battery and the manipulable and non-manipulable items of the "Man-made Objects/Actions" battery.

Task	*N*	JJG	Control group			Modified *t* test
			Mean	SD	Range	
"Manipulable/Non-manipulable" battery						
Naming						
Manipulable man-made objects	16	8	14.50	1.19	12–16	−5.12***
Manipulable Actions	16	1	12.25	1.98	9–15	−5.35***
All manipulable	32	9	26.75	2.71	22–31	−6.16***
Non-manipulable man-made objects	16	9	13.75	1.67	11–16	−2.68*
Non-manipulable actions	16	5	14.87	0.83	14–16	−11.21***
All non-manipulable	32	14	28.65	1.99	25–31	−6.90***
Word/picture verification						
Manipulable man-made objects	16	11	15.00	1.07	13–16	−3.52**
Manipulable actions	16	10	14.87	0.83	14–16	−5.53***
All manipulable	32	21	29.87	1.13	28–31	−7.40***
Non-manipulable man-made objects	16	12	14.75	1.28	13–16	−2.02
Non-manipulable actions	16	10	15.62	0.52	15–16	−10.20***
All non-manipulable	32	22	30.37	1.19	29–32	−6.63***
"Man-made Objects/Actions" battery						
Naming						
Session 1						
Manipulable items	30	9	27.85	1.34	26–30	−23.42***
Non-manipulable items	26	8	24.42	1.61	22–26	−15.75***
Session 2						
Manipulable items	30	12	27.85	1.34	26–30	−19.74***
Non-manipulable items	26	9	24.42	1.61	22–26	−14.79***
Session 3						
Manipulable items	30	13	27.85	1.34	26–30	−18.52***
Non-manipulable items	26	10	24.42	1.61	22–26	−13.83***
Word-picture matching						
Manipulable items	30	23	29.25	0.70	28–30	−8.42***
Non-manipulable items	26	17	25.62	0.74	24–26	−10.99***
Word/picture verification						
Session 1						
Manipulable items	30	8	27.85	1.34	26–30	−13.97***
Non-manipulable items	26	5	24.42	1.61	22–26	−11.37***
Session 2						
Manipulable items	30	12	27.85	1.34	26–30	−11.15***
Non-manipulable items	26	7	24.42	1.61	22–26	−10.20***
Session 3						
Manipulable items	30	10	27.85	1.34	26–30	−12.56***
Non-manipulable items	26	7	24.42	1.61	22–26	−10.20***

* $p < 0.05$.
** $p < 0.01$.
*** $= p < 0.001$.

impaired to a similar degree). This finding of an association between a deficit for man-made objects and for actions seems problematic for the hypothesis that objects and actions are separated at the conceptual level of processing (e.g., McCarthy & Warrington, 1985; Vigliocco et al., 2004). Not only our findings showed that a dissociation may occur within the class of "objects" (which is already a well-known fact) but also that a subclass of objects, that is, man-made objects, may pattern with actions following brain damage.

Admittedly, the association of a conceptual deficit for both man-made objects and actions in JJG could be explained by the mere co-occurrence of two deficits arising from two independent functional systems (or two distinct regions within a single semantic space; e.g., Caramazza, Hillis, Rapp, & Romani, 1990; Vigliocco et al., 2004) being fortuitously damaged, one affecting a system (or a region within the semantic space) representing and processing knowledge of man-made objects, the other impairing a system (or a region) representing and processing knowledge of actions. In that case, our findings would be no more problematic for the hypothesis of a conceptual separation between objects and actions.[7] However, we presented several arguments supporting the view that the association of a conceptual deficit for both man-made objects and actions in JJG was likely not arising by chance. We found that knowledge of man-made objects and of actions was consistently impaired to a similar degree of severity in various tasks like word/picture matching, word/picture verification, and property verification, with different subsets of items, and at different time periods. If we acknowledge that the empirical value of an association of deficits is weak when the deficits are not of similar severity or when their relative severity is not reported (e.g., Warrington & McCarthy, 1987; Warrington & Shallice, 1984), we believe that this is not or, at least, less the case when, like in this study, the severity of the deficit appears similar across various tasks, item sets, and time. An additional argument supporting the view that the association of conceptual deficits in JJG may not arise by chance is the existence of the inverse pattern of conceptual impairment, recently reported by Pillon and d'Honincthun (submitted for publication-b). The case GC they reported on showed a significantly disproportionate conceptual impairment for living things compared to man-made objects and actions, which were similarly impaired. Thus, GC's performance showed a consistent pattern of similar level of impairment for both man-made objects and actions in a variety of tasks such as naming photographs, understanding words and pictures, verifying verbally presented semantic properties, and pantomiming the way

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[7] Provided that the hypothesis specifies that, within the conceptual system, the representation of *each* of the three categories of objects (animals, plants, and man-made objects) is separate from the representation of actions.

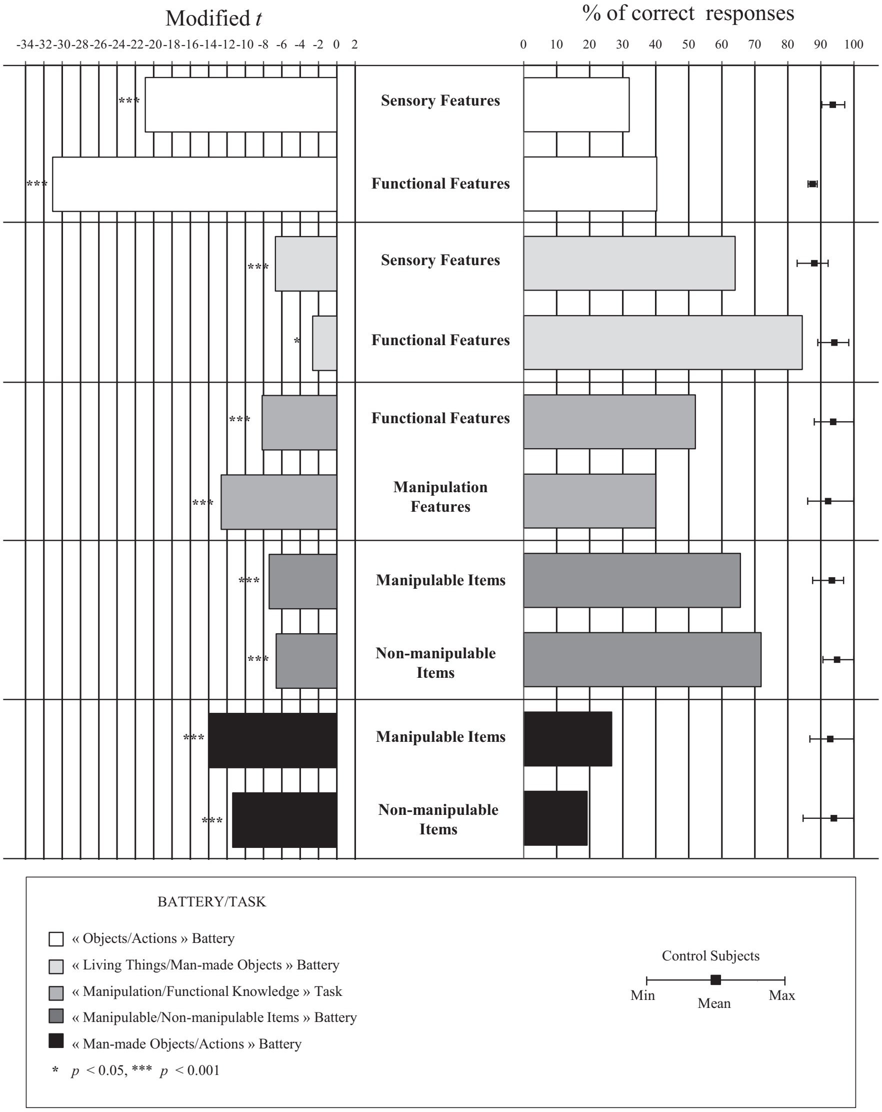

Fig. 3. Summary of JJG's and control subjects' results in the tasks assessing knowledge of sensory, functional, and manipulation features (i.e., in the property verification task with the items of the "Objects/Actions" and of the "Living Things/Man-made Objects" batteries and the "Manipulation/Functional Knowledge" task), and in the word/picture verification task contrasting manipulable to non-manipulable items (from the "Manipulable/Non-manipulable Items" and the "Man-made Objects/Actions" batteries). On the right, the figure displays the percentage of JJG's correct responses with the mean percentage and range (min–max) of correct responses of the control subjects and, on the left, the results of the modified *t*-tests for the comparison between JJG's and control subjects' performance.

in which the objects are used or the actions performed. The double dissociation represented by JJG' and GC's pattern (observed in part with the same material) not only weakens a chance account for the association of a deficit for man-made objects and a deficit for actions found in JJG, it also allows us to rule out an account for the association in terms of higher sensitivity to conceptual damage of these classes of concepts.

In a second step, we asked whether the "sensory/functional" or the "manipulability" account for category-specific conceptual deficits, both formulated within the framework of the FBO theory of the organization of knowledge in the mind and brain, and the "failure-of-simulating" hypothesis could account for the association of deficits observed in JJG. Within these three accounts, concepts of man-made objects and of actions would pattern together in the condition of damage to the conceptual system by virtue of their sharing a representational/processing system that is crucial for both these classes of concepts, that is, respectively, the functional property representational system, the manipulation representational system, and the hand movement production system. None of these accounts was supported by the data: JJG's conceptual impairment for man-made objects and actions was not associated with a disproportionate impairment for functional compared to sensory knowledge or manipulation compared to functional knowledge, and it did not affect manipulable more than non-manipulable items. In particular, even if JJG indeed had damage to motor processes involved in the planning and execution of hand/arm movements, which caused him upper limb apraxia (Cf. Section 2), such damage could not explain his impairment for man-made objects and actions that also concerned objects and actions that do not involve manual motor representation (i.e., non-manipulable objects and non-manual actions).

4.2. A domain-specific knowledge account for JJG's association of deficits

If these accounts within the FBO theory and the motor simulation framework are to be rejected, how can we explain the pattern of association found in JJG's conceptual impairment? We will propose here, following Pillon and d'Honincthun (submitted for publication-b), that conceptual knowledge of man-made objects and of human actions share a common, specialized, domain-specific representational and processing system which is responsible for the human ability to creatively, quickly, and efficiently design and understand means to achieving specific goals and purposes.

Currently most popular theories of the organization of conceptual knowledge in the mind and brain assume that the organization of conceptual knowledge is determined by the intrinsic properties of the stimuli that are to be recognized and categorized, such as the kinds of features they involve (Humphreys & Forde, 2001; Martin et al., 2000; Warrington & McCarthy, 1987; Warrington & Shallice, 1984) or the sensory and motor images they evoke (Barsalou, 1999; Barsalou, 2008; Barsalou, Simmons, Barbey, & Wilson, 2003; Damasio, 1989; Gallese & Lakoff, 2005; Meyer & Damasio, 2009). Instead, we propose that one organizing principle for conceptual knowledge could be an extrinsic property of stimuli like the reason why, for a given organism, conceptual knowledge about different kinds of stimuli is acquired, stored, and processed. Under this assumption, concepts of man-made objects and of human actions would be learned, stored, and processed by a common conceptual system whose function would be to provide human beings with a highly efficient problem-solving system needed for quickly and efficiently designing and understanding means to achieve specific goals and purposes.

This view, that the mind and brain have evolved cognitive and neural subsystems not because of the intrinsic characteristics of the input but because of the different functions to be achieved, is not new. Since 1980, psychologists have defended the view that the brain has evolved specialized devices designed to cope with specific types of problems (Fodor, 1983; Gardner, 1983; Marr, 1982). A core assumption in evolutionary functionalist research (Cosmides & Tooby, 1994; Cosmides & Tooby, 1995; Tooby & Cosmides, 1995) is that functional circuits have evolved to perform specialized functions so that they are primarily composed of problem-solving devices. The same idea could be found in cognitive neuroscience. Goodale and Milner (1992) (see also Milner and Goodale, 2006), for example, criticized the input-driven initial conception of the ventral and dorsal visual streams proposed by Ungerleider and Mishkin (1982) and instead defended that the ventral/dorsal organization was driven by the outputs of the two visual processing systems. Thus, separate processing streams would have evolved to sustain different behaviors, that is, the perceptual representation of our surrounding world, on the one hand, the visual control of actions, on the other hand.

We propose that the organization of conceptual knowledge for man-made objects and actions has been determined by such a principle. It is easy to agree, indeed, that designing actions according to one's purpose and understanding others', first, are very important functions in everyday life, second, rely on conceptual knowledge of both man-made objects and actions, and third, would benefit from the joint processing of action and man-made object knowledge. Thus, a specialized device designed to process altogether concepts of man-made objects and of actions could have evolved to achieve these functions.

This hypothesis seems reasonable also in light of empirical evidence in the developmental literature that shows that the acquisition of concepts of man-made objects and of actions is mediated by very similar learning principles. Thus, infants show a tendency to apprehend both actions (e.g., Csibra & Gergely, 2007; Gergely, Bekkering, & Kiraly, 2002; Gergely & Csibra, 2003) and man-made objects (e.g., Hernik & Csibra, 2009; Kelemen, 1999) in terms of the *goals* they permit to achieve. For example, Gergely et al. (2002) have shown that infants, among several elements, primarily pay attention to the physical features of the action, that causally contribute to the achievement of a goal. Thus, when 14 month children watch to an adult, whose hands are tied, using his head to turn on a light, and are asked to imitate the action, they imitated the action with their hands, revealing that they understand actions on the basis of a rational analysis of the goal to be achieved.

A similar goal-based principle is used to construct concepts of man-made objects. Träuble and Pauen (2007), for example, have shown that, after being presented with the use of unfamiliar man-made objects, infants are able to attend to their functionally relevant physical features, i.e., the features that causally contribute to the achievement of a goal, to categorize them. In their study, 11- to 12-month-old infants were presented with short demonstrations in which various novel man-made objects with a common functional part (a T-shaped projection) were used to achieve a common goal (e.g., pulling a pair of hooks out of the apparatus). After this familiarization phase, when presented with new pairs of objects, infants explored more shortly objects with the previously seen functionally relevant feature (orientation of the critical T-shaped part) than objects that lacked this feature. This was not the case when they did not see the demonstration of the functional use of the objects or when they saw non-functional demonstrations (i.e., producing no effect). This suggests that infants are able to categorize new man-made objects on the basis of their functional features as soon as they had been shown the functional use of the objects. Later on, verbal children, when confronted to a novel man-made object, immediately try to catch its intended function by asking questions about its functions, i.e., the goal-directed action in which it is used (Greif, Kemler Nelson, Keil, & Gutierrez, 2006; Kemler Nelson, Egan, & Holt, 2004); furthermore, they rely on a "common-function" principle to extend the name of a man-made object to a novel one (Kemler Nelson, 1995).

In sum, thanks to his/her early tendency to consider actions and man-made objects as means to achieve goals, the child builds his/her conceptual knowledge by discovering the several possible goals of actions, the functions of man-made objects, and how actions with man-made objects may enable a goal to be achieved (Csibra & Gergely, 2007). We assume that this learning principle lies at the heart of the acquisition and storing of knowledge about man-made objects and human actions by a common, domain-specific, conceptual system. This system would represent and process all kinds of concepts whose core property is that of being a mean of achieving a goal. Because both tools or other manipulable objects (e.g., a hammer or a coat) and non-manipulable objects (e.g., a bookcase or a car) and both manual (e.g., cutting) and whole-body (e.g., running) actions are conceptualized as means to achieve a goal, knowledge of the various categories of man-made objects and of goal-directed human actions is assumed to be not segregated within this common, specialized, domain-specific system.

Within this specialized system, tools would thus not have a special status compared to other man-made objects. Contrary to the suggestion made within the domain-specific knowledge theory (Mahon & Caramazza, 2009) with which we share the evolutionary perspective, we propose here that this specialized domain-specific system has evolved in humans not because adaptation for efficiently *recognizing* or *using* tools had fitness value but rather because adaptation for efficiently *designing* these tools had fitness value and this would be part of a more general adaptation for efficiently designing means to achieving specific goals and needs. Indeed, in our hunter–gatherer ancestors, it is likely that the ability to *design* and manufacture artifacts (e.g., weapons, containers, clothing, shelters, and tools to manufacture these artifacts) had survival and reproductive value.

Furthermore, we propose that this system is domain-specific in the sense that it would store and process all kinds of conceptual knowledge related to man-made objects – not only their function but also knowledge of their shape, texture, color, 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). Planning and understanding means to achieve goals indeed would benefit from such an extended base of knowledge about man-made objects and actions.[8] Therefore, in case of damage to this domain-specific conceptual system, all types of knowledge about any type of man-made objects and goal-directed human actions should be similarly impaired (everything else being equal).

The proposal of a shared conceptual system for man-made objects 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 man-made objects (the 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, processing man-made objects 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 non-action stimuli and during naming, auditory word comprehension, and conceptual judgment of action names compared to non-action names (Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008; Damasio et al., 2001; Grezes & Decety, 2001; Kable et al., 2005; Noppeney et al., 2005). The precise function of each part of this network is still poorly understood. However, specific activity within the left middle posterior temporal region was found during retrieval of conceptual knowledge related to both manipulable and non-manipulable man-made objects (Kellenbach et al., 2003) and during retrieval of conceptual knowledge related to both manual and whole-body actions (Corina et al., 2007; Noppeney et al., 2005). Strong activity within the same region was also found during semantic judgments related to five classes of verbs (running, speaking, hitting, cutting, and change of state verbs) 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 the left middle posterior temporal region is not dependent on the specific sensori-motor features of man-made objects and actions and may thus reflect the retrieval of property- and modality-independent representations of man-made objects and actions (see also Bedny et al., 2008; Binder et al., 2009; Mummery et al., 1998). It is reasonable to put forward the hypothesis that the left middle posterior temporal region – which was damaged in JJG – constitutes the neural substrate of a domain-specific conceptual system representing knowledge of all kinds of man-made objects and human actions.

4.3. Is there empirical evidence that contradicts the hypothesis of a common system for representing knowledge of man-made objects and of actions?

To the best of our knowledge, no previous neuropsychological study, either in the field of category-specific conceptual disorders or in the field of grammatical category-specific deficits, has investigated the issue addressed in this study (except Pillon and d'Honincthun, submitted for publication-b). Therefore, no one separately assessed knowledge of living things, man-made objects, and actions in the same design. There is thus no direct evidence available to date, but a few studies reported some results related to the assessment of man-made object and action processing in brain-damaged patients.

Thus, Ferreira, Giusiano, and Poncet (1997) reported on three patients whose performance in both naming and comprehension tasks was worse for animals than for tools. The patients' performance in naming action photographs was also reported and showed that action naming was relatively spared in comparison with naming animals, which suggested that tools and actions patterned together in comparison with animals in naming. However, no statistical contrast was reported between the naming of tools and actions and, furthermore, the comprehension of actions was not tested.

Three studies may seem to report a different pattern, that is, 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 were likely to differ both in the processing components involved and in difficulty. 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, first, with a "Picture Attribute Test", in which the patients were presented with two color photographs of actions and asked to choose the one that best met certain criteria (e.g., Which action would make the loudest noise?; Which action would require moving hands closer together?) and, second, with a "Picture Comparison Test", in which the patients had to select one from among three photographs that is 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. Among the 26 subjects that fit this criterion, 6 were impaired on just the Picture Attribute Test, 11 on just the Picture Comparison Test and only 9 were impaired 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 non-significant. 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 pre-conceptual deficit in recognizing or inferring the movements in the static pictures of actions (d'Honincthun & Pillon, 2008).

Bi, Han, Shu, and Caramazza (2007) reported on the single case study of ZBL and claimed that his pattern of performance supported the hypothesis that tool and action concepts can be damaged independently. This conclusion was, however, not at all warranted by the results. First of all, there was no one task, in

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[8] Our proposal has some resemblance to the praxis conceptual system suggested by Roy (1983) (see also Roy and Square, 1985), since this praxis conceptual system is also assumed to represent some aspects of both man-made object 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, that is, knowledge of the specific mechanical advantages provided by tools or of the specific mechanical requirements to achieve a manual action goal on an object, whereas, in our view, any kind of conceptual knowledge (e.g., perceptual, functional, associative knowledge) related to all man-made objects 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 the domain-specific conceptual system.

that study, that specifically comprised tool items. Tool items were always mixed with other man-made objects such as clothing, furniture, kitchenware, and vehicles and no separate result for tools compared to other man-made objects was reported. Second, and more importantly, action and man-made object items never were directly matched or contrasted in any task or by any statistic analysis: actions *vs.* (both living and man-made) objects were tested in two noun/verb picture naming tasks and man-made objects *vs.* animals were tested in another picture naming and an attribute judgment task. The results showed that ZBL'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 man-made objects and it was more impaired for man-made objects (44%) than animals (57%). In the attribute judgment task, ZBL's performance was impaired for man-made objects (73%) but not for animals (83%). This pattern suggested that ZBL probably had a conceptual impairment for man-made objects 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 man-made objects.

The third case report that has to be discussed here is the case EA (Laiacona & Caramazza, 2004). EA presented with a category-specific conceptual deficit for animals. Moreover, like ZBL, EA showed worse performance in naming nouns (42%) than verbs (82%); he was also worse at naming the man-made objects (22%) than the actions (85%) presented in the same pictures. However, EA was unimpaired in a word/picture matching task for both man-made objects (98%) and actions (100%), which suggest 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 man-made objects more than actions, a pattern of a grammatical category-specific deficit that is far from being uncommon (e.g., Berndt, Mitchum, Haendiges, & Sandson, 1997; Bird et al., 2000; Breedin, Saffran, & Schwartz, 1998; Miceli, Silveri, Nocentini, & Caramazza, 1988; Shapiro & Caramazza, 2003a; Shapiro & Caramazza, 2003b; Zingeser & Berndt, 1988).

Overall, the patterns of performance shown by ZBL and EA might indicate the existence of two independent functional loci of deficit in both patients. ZBL had a deficit at the conceptual level of processing affecting man-made objects (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, EA had a deficit at the conceptual level affecting animals more than man-made objects and actions, further to an additional deficit at the level of the phonological form retrieval affecting nouns more than verbs, like in ZBL. We acknowledge that these interpretations are speculative because of 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 man-made objects and actions.

Finally, there are findings in the tradition of apraxia research that may seem to contradict the hypothesis of a common conceptual system for representing knowledge of man-made objects and of actions. Patients have been reported who could name and recognize man-made objects – which suggested that conceptual knowledge of man-made objects was spared in these patients – while they could not demonstrate how to use them – which suggested that "action-related knowledge" for man-made objects was impaired (e.g., Negri et al., 2007; Rosci, Chiesa, Laiacona, & Capitani, 2003). 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 achieving a given activity with a given object while by "concepts of action" we mean all kinds of conceptual knowledge related to a category of goal-directed activities (an action), which includes knowledge of its goal, causes and consequences, the objects, people and instruments it generally involves, the typical context in which it takes place, its emotional content, etc. (Tranel et al., 2003). Our hypothesis could be rejected if it were shown that patients could name and recognize man-made objects 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).

4.4. Conclusion

We have reported on the single-case study of a brain-damaged patient presenting with a severe impairment of conceptual knowledge of man-made objects and of actions while his knowledge of plant-life, animals, and other categories of objects like famous people, countries, and famous buildings, was spared. We then showed that, contrary to the predictions made by the "sensory/functional", the "manipulability", and the "failure-of-simulating" accounts for category-specific conceptual impairments, the patient's association of deficits for both man-made objects and actions was not associated with a disproportionate impairment of functional compared to sensory knowledge or of manipulation compared to functional knowledge; manipulable items were not more impaired than non-manipulable items either. We propose to account for the patient's association of deficits by the hypothesis that concepts whose core property is that of being a mean of achieving a goal – like the concepts of man-made objects and of actions – are learned, represented, and processed by a common, domain-specific conceptual system, which would have evolved to allow human beings to creatively, quickly, and efficiently design and understand means to achieve goals and purposes.

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Appendix.

Distribution of JJG's errors (in % of total errors) in the naming and the word/picture verification tasks of the "Objects/Actions", "Concrete Objects", and "Man-Made Objects/Actions" battery.

Battery	Naming Error types			Word/picture verification Error types			
	Non-response and unrelated	Semantic paraphasia	Other	Rejection of the correct picture	Acceptance of a close semantic foil	Acceptance of a far semantic foil	Acceptance of an unrelated foil
“Objects/Actions”							
Living things	78	22	0	0	100	0	0
Man-made objects	73	27	0	25	50	25	0
Action/photographs	72	24	4	3	47	32	18
Actions/videos	62	28	10	9	50	28	12
“Concrete Objects”							
Animals	61	39	0	0	90	n.a.	0
Plants	65	35	0	0	100	n.a.	0
Man-made objects	56	44	0	0	100	n.a.	0
“Man-Made Objects/Actions”							
Man-made objects	53	39	8	0	100	n.a.	0
Actions	55	36	9	0	92	n.a.	0

References

Alario, F. X., & Ferrand, L. (1999). A set of 400 pictures standardized for French: Norms for name agreement, image agreement, familiarity, visual complexity, image variability, and age of acquisition. *Behavior Research Methods Instruments and Computers*, *3*, 531–552.

Allport, D. A. (1985). Distributed memory, modular subsystems and dysphasia. In S. K. Newman, & R. Epstein (Eds.), *Current perspectives in dysphasia* (pp. 32–60). New York: Churchill Livingstone.

Baddeley, A. D., Emslie, H., & Nimmo-Smith, I. (1994). *Doors and people: A test of visual and verbal recall and recognition*. Bury St. Edmunds, UK: Thames Valley Test Company.

Bak, T. H., & Hodges, J. R. (2003). Kissing and dancing – A test to distinguish the lexical and conceptual contributions to noun/verb and action/object dissociation. Preliminary results in patients with frontotemporal dementia. *Journal of Neurolinguistics*, *16*, 169–181.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*, 577–609.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*, 617–645.

Barsalou, L. W., Simmons, W. K., Barbey, A. K., & Wilson, C. D. (2003). Grounding conceptual knowledge in modality-specific systems. *Trends in Cognitive Sciences*, *7*, 84–91.

Bedny, M., Caramazza, A., Grossman, E., Pascual-Leone, A., & Saxe, R. (2008). Concepts are more than percepts: The case of action verbs. *The Journal of Neuroscience*, *28*, 11347–11353.

Bergego, C., Pradat-Diehl, P., & Ferrand, I. (2006). *Batterie de décision visuelle d'objets*. Isbergues, France: Ortho-Edition.

Berndt, R. S., Mitchum, C. C., Haendiges, A. N., & Sandson, J. (1997). Verb retrieval in aphasia. 1. Characterizing single word impairments. *Brain and Language*, *56*, 68–106.

Bi, Y. C., Han, Z. Z., Shu, H., & Caramazza, A. (2007). Nouns, verbs, objects, actions, and the animate/inanimate effect. *Cognitive Neuropsychology*, *24*, 485–504.

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex*, *19*, 2767–2796.

Bird, H., Howard, D., & Franklin, S. (2000). Why is a verb like an inanimate object? Grammatical category and semantic category deficits. *Brain and Language*, *72*, 246–309.

Bonin, P., Boyer, B., Meot, A., Fayol, M., & Droit, S. (2004). Psycholinguistic norms for action photographs in French and their relationships with spoken and written latencies. *Behavior Research Methods Instruments and Computers*, *36*, 127–139.

Bonin, P., Meot, A., Aubert, L., Malardier, N., Niedenthal, P., & Capelle-Toczek, M.-C. (2003). Normes de concrétude, de valeur d'imagerie, de fréquence subjective et de valence émotionnelle pour 866 mots [Concreteness, imageability, subjective frequency, and emotional valence norms for a set of 866 French words]. *L'Année psychologique*, *104*, 655–694.

Bonin, P., Peereman, R., Malardier, N., Meot, A., & Chalard, M. (2003). A new set of 299 pictures for psycholinguistic studies: French norms for name agreement, image agreement, conceptual familiarity, visual complexity, image variability, age of acquisition, and naming latencies. *Behavior Research Methods Instruments and Computers*, *35*, 158–167.

Breedin, S. D., Saffran, E. M., & Schwartz, M. F. (1998). Semantic factors in verb retrieval: An effect of complexity. *Brain and Language*, *63*, 1–31.

Buxbaum, L. J., & Saffran, E. M. (2002). Knowledge of object manipulation and object function: Dissociations in apraxic and nonapraxic subjects. *Brain and Language*, *82*, 179–199.

Capitani, E., Laiacona, M., Mahon, B., & Caramazza, A. (2003). What are the facts of semantic category-specific deficits? A critical review of the clinical evidence. *Cognitive Neuropsychology*, *20*, 213–261.

Caramazza, A., Hillis, A. E., Rapp, B. C., & Romani, C. (1990). The multiple semantics hypothesis: Multiple confusions? *Cognitive Neuropsychology*, *7*, 161–189.

Caramazza, A., & Shelton, J. R. (1998). Domain-specific knowledge systems in the brain: The animate–inanimate distinction. *Journal of Cognitive Neuroscience*, *10*, 1–34.

Chao, L. L., & Martin, A. (2000). Representation of manipulable man-made objects in the dorsal stream. *NeuroImage*, *12*, 478–484.

Corina, D., Chiu, Y. S., Knapp, H., Greenwald, R., San Jose-Robertson, L., & Braun, A. (2007). Neural correlates of human action observation in hearing and deaf subjects. *Brain Research*, *1152*, 111–129.

Cosmides, L., & Tooby, J. (1994). Origins of domain-specificity: The evolution of functional organization. In L. Hirschfeld, & S. Gelman (Eds.), *Mapping the mind: Domain-specificity in cognition and culture* (pp. 85–117). New York: Cambridge University Press.

Cosmides, L., & Tooby, J. (1995). From function to structure: The role of evolutionary biology and computational theories in cognitive neuroscience. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1199–1210). Cambridge, MA: MIT Press.

Crawford, J. R., & Garthwaite, P. H. (2005). Testing for suspected impairments and dissociations in single-case studies in neuropsychology: Evaluation of alternatives using Monte Carlo simulations and revised tests for dissociations. *Neuropsychology*, *19*, 318–331.

Crawford, J. R., & Garthwaite, P. H. (2007). Comparison of a single case to a control or normative sample in neuropsychology: Development of a Bayesian approach. *Cognitive Neuropsychology*, *24*, 343–372.

Crawford, J. R., & Howell, D. C. (1998). Comparing an individual's test score against norms derived from small samples. *The Clinical Neuropsychologist*, *12*, 482–486.

Cree, G. S., & McRae, K. (2003). Analyzing the factors underlying the structure and computation of the meaning of *chipmunk*, *cherry*, *chisel*, *cheese*, and *cello* (and many other such concrete nouns). *Journal of Experimental Psychology: General*, *132*, 163–201.

Creem-Regehr, S. H., & Lee, J. N. (2005). Neural representations of graspable objects: Are tools special? *Cognitive Brain Research*, *22*, 457–469.

Crutch, S. J., & Warrington, E. K. (2003). The selective impairment of fruit and vegetable knowledge: A multiple processing channels account of fine-grain category specificity. *Cognitive Neuropsychology*, *20*, 355–372.

Csibra, G., & Gergely, G. (2007). "Obsessed with goals": Functions and mechanisms of teleological interpretation of actions in humans. *Acta Psychologica*, *124*, 60–78.

Cubelli, R., Marchetti, C., Boscolo, C., & Della Sala, S. (2000). Cognition in action: Testing a model of limb apraxia. *Brain and Cognition*, *44*, 144–165.

Damasio, A. R. (1989). Time-locked multiregional retroactivation: A systems-level proposal for the neural substrates of recall and recognition. *Cognition*, *33*, 25–62.

Damasio, A. R., & Tranel, D. (1993). Nouns and verbs are retrieved with differently distributed neural systems. *Proceedings of the National Academy of Sciences of the United States of America*, *90*, 4957–4960.

Damasio, H., Grabowski, T. J., Tranel, D., Ponto, L. L. B., Hichwa, R. D., & Damasio, A. R. (2001). Neural correlates of naming actions and of naming spatial relations. *NeuroImage*, *13*, 1053–1064.

de Partz, M.-P., Bilocq, V., De Wilde, V., Seron, X., & Pillon, A. (2001). *LEXIS. Tests pour le diagnostic des troubles lexicaux chez le patient aphasique*. Marseille, France: Solal.

Devlin, J. T., Gonnerman, L. M., Andersen, E. S., & Seidenberg, M. S. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience*, *10*, 77–94.

d'Honincthun, P., & Pillon, A. (2008). Verb comprehension and naming in frontotemporal degeneration: The role of the static depiction of actions. *Cortex*, *44*, 834–847.

Druks, J. (2002). Verbs and nouns – A review of the literature. *Journal of Neurolinguistics*, *15*, 289–315.

Farah, M. J., & McClelland, J. L. (1991). A computational model of semantic memory impairment: Modality specificity and emergent category specificity. *Journal of Experimental Psychology: General*, *120*, 339–357.

Ferreira, C. T., Giusiano, B., & Poncet, M. (1997). Category-specific anomia: Implication of different neural networks in naming. *Neuroreport*, *8*, 1595–1602.

Fodor, J. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.

Gainotti, G., Silveri, M. C., Daniele, A., & Giustolisi, L. (1995). Neuroanatomical correlates of category-specific semantic disorders: A critical survey. *Memory*, *3*, 247–264.

Gallese, V., & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology*, *22*, 455–479.

Gardner, H. (1983). *Frames of mind. The theory of multiple intelligences*. New York: Basic Books.

Gergely, G., Bekkering, H., & Kiraly, I. (2002). Rational imitation in preverbal infants. *Nature*, *415*, 755–1755.

Gergely, G., & Csibra, G. (2003). Teleological reasoning in infancy: The naive theory of rational action. *Trends in Cognitive Sciences*, *7*, 287–292.

Gerlach, C., Law, I., & Paulson, O. B. (2002). When action turns into words. Activation of motor-based knowledge during categorization of manipulable objects. *Journal of Cognitive Neuroscience*, *14*, 1230–1239.

Gerstmann, J. (1940). Syndrome of finger agnosia, disorientation for right and left, agraphia and acalculia. *Archives of Neurology and Psychiatry*, *44*, 398–407.

Goldenberg, G. (1995). Imitating gestures and manipulating a manikin – The representation of the human-body in ideomotor apraxia. *Neuropsychologia*, *33*, 63–72.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences*, *15*, 20–25.

Greif, M. L., Kemler Nelson, D., Keil, F., & Gutierrez, F. (2006). What do children want to know about animals and artifacts? Domain-specific requests for information. *Psychological Science*, *17*, 455–459.

Grezes, J., & Decety, J. (2001). Functional anatomy of execution, mental simulation, observation, and verb generation of actions: A meta-analysis. *Human Brain Mapping*, *12*, 1–19.

Hernik, M., & Csibra, G. (2009). Functional understanding facilitates learning about tools in human children. *Current Opinion in Neurobiology*, *19*, 34–38.

Howard, D., & Patterson, K. (1992). *The pyramids and palm trees test. A test of semantic access from words and pictures*. Bury St Edmunds, UK: Thames Valley Test Company.

Humphreys, G. W., & Forde, E. M. E. (2001). Hierarchies, similarity, and interactivity in object recognition: “Category-specific” neuropsychological deficits. *Behavioral and Brain Sciences*, *24*, 453–509.

Humphreys, G. W., Riddoch, M. J., & Quinlan, P. T. (1988). Cascade processes in picture identification. *Cognitive Neuropsychology*, *5*, 67–103.

Kable, J. W., Kan, I. P., Wilson, A., Thompson-Schill, S. L., & Chatterjee, A. (2005). Conceptual representations of action in the lateral temporal cortex. *Journal of Cognitive Neuroscience*, *17*, 1855–1870.

Kalénine, S., Peyrin, C., Pichat, C., Segebarth, C., Bonthoux, F., & Baciu, M. (2009). The sensory-motor specificity of taxonomic and thematic conceptual relations: A behavioral and fMRI study. *NeuroImage*, *44*, 1152–1162.

Kelemen, D. (1999). Function, goals and intention: Children’s teleological reasoning about objects. *Trends in Cognitive Sciences*, *3*, 461–468.

Kellenbach, M. L., Brett, M., & Patterson, K. (2003). Actions speak louder than functions: The importance of manipulability and action in tool representation. *Journal of Cognitive Neuroscience*, *15*, 30–46.

Kemler Nelson, D. (1995). Principle-based inferences in young children’s categorization: Revisiting the impact of function on the naming of artifacts. *Cognitive Development*, *10*, 347–380.

Kemler Nelson, D., Egan, L., & Holt, M. (2004). When children ask What is it? What do they want to know about artifacts? *Psychological Science*, *15*, 384–389.

Kemmerer, D., Gonzalez Castillo, J., Talavage, T., Patterson, S., & Wiley, C. (2008). Neuroanatomical distribution of five semantic components of verbs: Evidence from fMRI. *Brain and Language*, *107*, 16–43.

Laiacona, M., & Caramazza, A. (2004). The noun/verb dissociation in language production: Varieties of causes. *Cognitive Neuropsychology*, *21*, 103–123.

Lewis, J. W., Brefczynski, J. A., Phinney, R. E., Janik, J. J., & DeYoe, E. A. (2005). Distinct cortical pathways for processing tool versus animal sounds. *The Journal of Neuroscience*, *25*, 5148–5158.

Luria, A. (1980). *Higher cortical functions in man*. New York: Basic Books Inc Publishers.

Mahon, B. Z., & Caramazza, A. (2009). Concepts and categories: A cognitive neuropsychological perspective. *Annual Review of Psychology*, *60*, 27–51.

Marr, D. (1982). *Vision: A computational investigation into the human representation and processing of visual information*. San Francisco, CA: W.H. Freeman.

Martin, A., Ungerleider, L. G., & Haxby, J. V. (2000). Category-specificity and the brain: The sensory-motor model of semantic representations of objects. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (2nd ed., pp. 1023–1036). Cambridge: MIT Press.

Mätzig, S., Druks, J., Masterson, J., & Vigliocco, G. (2009). Noun and verb differences in picture naming: Past studies and new evidence. *Cortex*, *45*, 738–758.

McCarthy, R., & Warrington, E. K. (1985). Category specificity in an agrammatic patient: The relative impairment of verb retrieval and comprehension. *Neuropsychologia*, *23*, 709–727.

McRae, K., de Sa, V. R., & Seidenberg, M. S. (1997). On the nature and scope of featural representations of word meaning. *Journal of Experimental Psychology: General*, *126*, 99–130.

Meyer, K., & Damasio, A. (2009). Convergence and divergence in a neural architecture for recognition and memory. *Trends in Neurosciences*, *32*, 376–382.

Miceli, G., Silveri, M. C., Nocentini, U., & Caramazza, A. (1988). Patterns of dissociation in comprehension and production of nouns and verbs. *Aphasiology*, *2*, 351–358.

Milner, A. D., & Goodale, M. A. (2006). *The visual brain in action* (2nd ed.). Oxford: Oxford University Press.

Moore, C. J., & Price, C. J. (1999). A functional neuroimaging study of the variables that generate category-specific object processing differences. *Brain*, *122*, 943–962.

Mummery, C. J., Patterson, K., Hodges, J. R., & Price, C. J. (1998). Functional neuroanatomy of the semantic system: Divisible by what? *Journal of Cognitive Neuroscience*, *10*, 766–777.

Negri, G. A. L., Rumiati, R. I., Zadini, A., Ukmar, M., Mahon, B. Z., & Caramazza, A. (2007). What is the role of motor simulation in action and object recognition? Evidence from apraxia. *Cognitive Neuropsychology*, *24*, 795–816.

New, B., Brysbaert, M., Veronis, J., & Pallier, C. (2007). The use of film subtitles to estimate word frequencies. *Applied Psycholinguistics*, *28*, 661–677.

Noppeney, U. (2008). The neural systems of tool and action semantics: A perspective from functional imaging. *Journal of Physiology-Paris*, *102*, 40–49.

Noppeney, U., Josephs, O., Kiebel, S., Friston, K. J., & Price, C. J. (2005). Action selectivity in parietal and temporal cortex. *Cognitive Brain Research*, *25*, 641–649.

Peigneux, P., & Van der Linden, M. (2000). Presentation of a cognitive neuropsychological battery for limb apraxia assessment. *Revue de Neuropsychologie*, *10*, 311–362.

Pillon, A., & d’Honincthun, P. The organization of the conceptual system: The case of the “object vs. action” dimension. *Cognitive Neuropsychology*, submitted for publication-a.

Pillon, A., & d’Honincthun, P. A common processing system for the concepts of artifacts and actions? Evidence from a case of a disproportionate conceptual impairment for living things. *Cognitive Neuropsychology*, submitted for publication-b.

Rapp, B., & Caramazza, A. (1998). A case of selective difficulty in writing verbs. *Neurocase*, *4*, 127–140.

Riddoch, M. J., & Humphreys, G. W. (1993). *The Birmingham Object Recognition Battery (BORB)*. Hove, UK: Psychology Press.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*, 169–192.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience*, *2*, 661–670.

Rosci, C., Chiesa, V., Laiacona, M., & Capitani, E. (2003). Apraxia is not associated to a disproportionate naming impairment for manipulable objects. *Brain and Cognition*, *53*, 412–415.

Rothi, L. J. G., Ochipa, C., & Heilman, K. M. (1991). A cognitive neuropsychological model of limb apraxia. *Cognitive Neuropsychology*, *8*, 443–458.

Rothi, L. J. G., Ochipa, C., & Heilman, K. M. (1997). A cognitive neuropsychological model of limb praxis and apraxia. In L. J. G. Rothi, & K. M. Heilman (Eds.), *Apraxia. The neuropsychology of action* (pp. 29–50). Hove, UK: Psychology Press.

Roy, E. A. (1983). Current perspectives on disruptions to limb praxis. *Physiological Therapy*, *63*, 1998–2003.

Roy, E. A., & Square, P. (1985). Common considerations in the studies of limb, verbal and oral apraxia. In E. A. Roy (Ed.), *Neuropsychological studies of apraxia and related disorders* (pp. 111–156). Amsterdam: Elsevier.

Saccuman, M. C., Cappa, S. F., Bates, E. A., Arevalo, A., Della Rosa, P., Danna, M., et al. (2006). The impact of semantic reference on word class: An fMRI study of action and object naming. *NeuroImage*, *32*, 1865–1878.

Samson, D., Pillon, A., & De Wilde, V. (1998). Impaired knowledge of visual and non-visual attributes in a patient with a semantic impairment for living entities: A case of a true category-specific deficit. *Neurocase*, *4*, 273–290.

Shapiro, K., & Caramazza, A. (2003a). Grammatical processing of nouns and verbs in left frontal cortex? *Neuropsychologia*, *41*, 1189–1198.

Shapiro, K., & Caramazza, A. (2003b). Looming a loom: Evidence for independent access to grammatical and phonological properties in verb retrieval. *Journal of Neurolinguistics*, *16*, 85–111.

Simmons, W. K., & Barsalou, L. W. (2003). The similarity-in-topography principle: Reconciling theories of conceptual deficits. *Cognitive Neuropsychology*, *20*, 451–486.

Smirni, P., Villardita, C., & Zappala, G. (1983). Influence of different paths on spatial memory performance in the Block-Tapping Test. *Journal of Clinical Neuropsychology*, *5*, 355–359.

Tooby, J., & Cosmides, L. (1995). Mapping the evolved functional organization of mind and brain. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1167–1178). Cambridge, MA: MIT Press.

Tranel, D., Kemmerer, D., Adolphs, R., Damasio, H., & Damasio, A. R. (2003). Neural correlates of conceptual knowledge for actions. *Cognitive Neuropsychology*, *20*, 409–432.

Träuble, B., & Pauen, S. (2007). The role of functional information for infant categorization. *Cognition*, *105*, 362–379.

Ungerleider, L., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.), *Analysis of visual behavior* (pp. 549–586). Cambridge, MA: MIT Press.

Vigliocco, G., Vinson, D. P., Lewis, W., & Garrett, M. F. (2004). Representing the meanings of object and action words: The featural and unitary semantic space hypothesis. *Cognitive Psychology*, *48*, 422–488.

Warrington, E. K., & McCarthy, R. A. (1983). Category specific access dysphasia. *Brain*, *106*, 859–878.

Warrington, E. K., & McCarthy, R. A. (1987). Categories of knowledge. Further fractionations and an attempted integration. *Brain*, *110*, 1273–1296.

Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain*, *107*, 829–854.

Zingeser, L. B., & Berndt, R. S. (1988). Grammatical class and context effects in a case of pure anomia: Implications for models of language production. *Cognitive Neuropsychology*, *5*, 473–516.