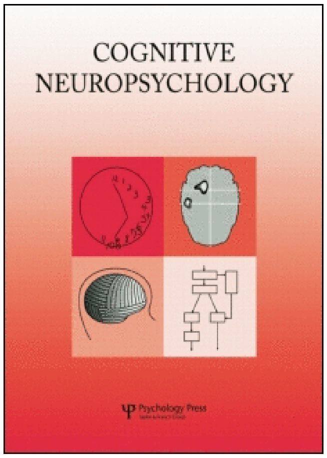

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What is the role of motor simulation in action and object recognition? Evidence from apraxia

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What is the role of motor simulation in action and object recognition? Evidence from apraxia

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An important issue in contemporary cognitive neuroscience concerns the role of motor production processes in perceptual and conceptual analysis. To address this issue, we studied the performance of a large group of unilateral stroke patients across a range of tasks using the same set of common manipulable objects. All patients ($n = 37$) were tested for their ability to demonstrate the use of the objects, recognize the objects, recognize the corresponding object-associated pantomimes, and imitate those same pantomimes. At the group level we observed reliable correlations between object use and pantomime recognition, object use and object recognition, and pantomime imitation and pantomime recognition. At the single-case level, we document that the ability to recognize actions and objects dissociates from the ability to use those same objects. These data are problematic for the hypothesis that motor processes are constitutively involved in the recognition of actions and objects and frame new questions about the inferences that are merited by recent findings in cognitive neuroscience.

Keywords: Apraxia; Embodied cognition; Action recognition; Object recognition.

A longstanding idea in cognitive science is that the same processes that mediate the production of actions are critically involved in perceptual and conceptual processing (e.g., Allport, 1985; Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Shiffrar & Freyd, 1990; Viviani & Stucchi, 1989). Recently, interest in the role of motor processes in perceptual and conceptual analysis has been

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stimulated by numerous observations, using a range of methodologies, that the motor system is activated in tasks that do not apparently require activation of the motor system. On the basis of such observations, many different formulations of motor theories of cognition have been proposed. For instance, it has been argued that motor processes are critically involved in speech perception (e.g., Fadiga, Craighero, Buccino, & Rizzolatti, 2002; Liberman et al., 1967), action recognition and understanding (Rizzolatti, Fogassi, & Gallese, 2001), the recognition of familiar objects (Gallese & Lakoff, 2005; Helbig, Graf, & Kiefer, 2006; Simmons & Barsalou, 2003), and understanding the intentions and mental states of others (Adolphs, 2003; Fogassi et al., 2005; Gallese & Goldman, 1998).

In this article we examine the role of those motor processes that subserve object use in recognizing visually presented object-associated actions and in recognizing visually presented objects. We focus on this particular topic for the following reason. Studying action recognition and object recognition offers a stringent test of the hypothesis that motor production processes play a critical (i.e., constitutive) role in perceptual and conceptual analysis. If (putatively) more "abstract" abilities, such as the attribution of mental states to other individuals, depend on activation of motor processes in the observer, then it would be likely that the more basic abilities of recognizing actions and objects would also depend on such motor activation.[1]

Cognitive neuropsychological analyses of apraxic patients provide a direct means for testing the degree to which motor systems are involved in the recognition of actions and objects. Ideational apraxia can be clinically defined as an impairment in using objects that cannot be attributed to aphasia, sensory impairment, or an impairment to basic motor responses (De Renzi & Lucchelli, 1988; Liepmann, 1920; Pick, 1905). Thus, if motor production systems are necessary in order to recognize actions and/or manipulable objects, then patients with apraxic impairments for using objects will necessarily be impaired for recognizing the actions associated with the use of those objects and/or recognizing the objects themselves.

Empirical and theoretical motivation for this project

There is a rich array of empirical evidence indicating that observers' motor systems are activated during observation of actions and manipulable objects. With respect to actions, Rizzolatti and colleagues (e.g., Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; for review see e.g., Rizzolatti & Craighero, 2004; Rizzolatti & Wolpert, 2005) have described a frontal-parietal circuit (F5-aIPS) in macaques that is active both when the monkey makes a goal-directed movement and when the monkey observes another individual (human or monkey) making a similar action. In humans, functional imaging studies have described a putatively homologous frontal-parietal circuit that is active when humans observe the actions of other humans (e.g., Buccino et al., 2004). Finally, studies using transcranial magnetic stimulation (TMS) have demonstrated the concurrent activation of motor cortices when participants observe the actions of another individual (Aziz-Zadeh, Maeda, Zaidel, Mazziotta, & Iacoboni, 2002; Baldissera, Cavallari, Craighero, & Fadiga, 2001; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; see also Maeda, Kleiner-Fisman, & Pascual-Leone, 2002, for discussion).

With respect to objects, a partially distinct, but overlapping, frontal-parietal circuit is activated upon presentation of graspable objects. In macaques, the F5-aIPS circuit is active both when the monkey grasps an object and when the monkey views an object that affords the same, or a similar, grasp (for review see e.g., Rizzolatti & Craighero, 2004; Rizzolatti & Wolpert, 2005).

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[1] This line of reasoning does not follow necessarily. It depends on how modular the cognitive systems involved in these various capacities are assumed to be. The above reasoning goes through only on a very general construal of the interdependence between putatively "higher order" social reasoning and "more basic" action recognition.

In humans, functional imaging studies have documented that posterior parietal and premotor areas are differentially activated when participants observe manipulable objects compared to nonmanipulable nonliving things and living things (Chao & Martin, 1999; Johnson-Frey, 2004; Kellenbach, Brett, & Patterson, 2003).

Such data indicate that observation of actions and manipulable objects results in activation of neural structures in the observer that mediate overt action. We refer to such automatic activation of motor production processes in the course of observing actions and manipulable objects as "motor simulation". A number of authors have argued on the basis of such activation evidence that motor simulation, as defined herein, is constitutively involved in perceptual and conceptual processing of actions and/or manipulable objects (e.g., Buxbaum, Kyle, & Menon, 2005; Gallese, 2005; Gallese & Lakoff, 2005; Helbig et al., 2006; Martin, Ungerleider, & Haxby, 2000; Pulvermüller, 2005; for an earlier proposal of this idea, see Allport, 1985). We refer to the hypotheses that the motor system is necessarily involved in action and object recognition as the motor theory of action recognition and the motor theory of object recognition, respectively. Two versions of the motor theories of action and object representation can be distinguished (for discussion, see Mahon & Caramazza, 2005). On one version, there is overlap in the processes subserving action production and action (and object) recognition. On a second version, while the processes subserving action production are functionally separable from those subserving the recognition of actions and objects, the activation of such motor processes is necessary in order for successful recognition to proceed. Critically, on both formulations of the motor theories of action/object recognition, the activation of motor information is necessary in order to successfully recognize and understand actions and objects.

Neuropsychological investigations of apraxic patients suggest that the ability to use objects is not necessary in order either to recognize those objects or to recognize the actions associated with their use. Previous authors have reported patients demonstrating impairments for using objects but relatively spared ability to recognize object-associated gestures (Bartolo, Cubelli, Della Sala, Drei, & Marchetti, 2001; Bergego, Pradat-Diehl, & Deloche, 1992; Dumont & Ska, 2000; Dumont, Ska, & Schiavetto, 1999; Halsband et al., 2001; Mozaz, Rothi, Anderson, Crucian, & Heilman, 2002; Ochipa, Rothi, & Heilman, 1989; Rapcsak, Ochipa, Anderson, & Poizner, 1995; Rumiati, Zanini, Vorano, & Shallice, 2001; Schwartz et al., 1995; for review and discussion see Cubelli, Marchetti, Boscolo, & Della Sala, 2000; Hodges, Bozeat, Lambon Ralph, Patterson, & Spatt, 2000; Johnson-Frey, 2004; Mahon & Caramazza, 2005; Rothi, Ochipa, & Heilman, 1991; Rumiati et al., 2001). On the basis of such dissociations, it has been proposed that there are separate input and output action "lexicons" (e.g., Rothi et al., 1991). In this article, we refer to such input and output representations as input and output "axemes". The term "axeme" is intended to evoke the analogy that has been drawn between models of apraxia and models of language processing. By analogy to models of language processing, input axemes refer to those representations that are tied to perceptual analysis of actions, while output axemes are those representations that are tied to processes subserving innervation of the effectors. We can refer to the model that assumes separate input and output axemes as the independent axemes model (IAM). The prediction of the IAM (see Cubelli et al., 2000; Rothi et al., 1991) is that an impairment for using objects will not necessarily be associated with an impairment for recognizing the corresponding object-associated movements.

Patients have also been reported who are impaired at using objects but not at identifying the same or similar objects or retrieving semantic information about those objects (Buxbaum & Saffran, 2002; Buxbaum, Sirigu, Schwartz, & Klatzky, 2003; Buxbaum, Veramonti, & Schwartz, 2000; Cubelli et al., 2000; Halsband et al., 2001; Hodges, Spatt, & Patterson, 1999; Montomura & Yamadori, 1994; Moreaud, Charnallet, & Pellat, 1998; Ochipa et al., 1989; Rapcsak et al., 1995; Rosci, Valentina, Laiacona, & Capitani, 2003;

Rumiati et al., 2001). The opposite side of this double dissociation is represented by those patients with semantic impairments who are still able to use objects correctly, despite a severe loss of visuosemantic knowledge about them (e.g., Buxbaum, Schwartz, & Carew, 1997; Hodges et al., 2000; Lauro-Grotto, Piccini, & Shallice, 1997; Negri, Lunardelli, Gigli, & Rumiati, 2007). Contrary to the motor theory of object recognition, such data suggest that the processes subserving object use are not necessary in order to recognize and understand objects, and vice versa.

Recently, however, a strong form of the motor theory of action recognition has been advocated on the basis of neuropsychological data. Buxbaum and colleagues (2005) analysed patterns of association of impairments across a group of patients on action imitation and action recognition tasks. A reliable correlation was observed between the performance of patients in recognizing pantomimes and their performance in imitating pantomimes. On the basis of the correlation observed between pantomime recognition and pantomime imitation, Buxbaum and colleagues argued that the same representations ground production and perception of object-directed (i.e., transitive) hand actions. Those authors proposed that such shared representations are located, neuroanatomically, in the left inferior parietal lobule. In a comparable analysis, Tessari, Canessa, Ukmar, and Rumiati (2007) reported a weak correlation between pantomime imitation and recognition ($r = .32, p = .07$), across a group of 32 consecutive patients with either left or right unilateral brain damage.

Studies based on analyses of large numbers of patients who are tested on the same materials and evaluated with the same methods and error criteria have the advantage of providing a relatively broad view of the relation between cognitive processes. At the same time, however, focusing only on correlations in performance across tasks at the group level runs the risk of overlooking single cases that present dissociations that are not in line with the group level trends. For this reason, the present study adopts both approaches. We study a large group of unselected patients in order to document group level correlations in performance across praxis tasks. We then provide analyses of the behavioural profiles at the single-case level to study potential exceptions to the group level pattern. Previous studies that have analysed the praxis performance of multiple patients within the same study, and across the same materials, either have focused only on group level trends (Buxbaum et al., 2005) or single-case analyses (Cubelli et al., 2000) or have not observed both the group level trends and the dissociations at the single-case level (Rosci et al., 2003; Tessari et al., 2007).

The substantive issues at stake in the present article are as follows. First, are output axemes functionally separable from input axemes and the processes subserving visual object recognition? Second, in the measure to which output axemes are functionally separable from input axemes and from processes subserving visual object recognition, is motor simulation (i.e., the activation of output axemes) necessary in order for successful recognition of actions and manipulable objects to occur? To anticipate our results, we reproduced both the correlations reported by Buxbaum and colleagues (2005) and the dissociations between object use and action recognition and between object use and object recognition, which have been reported in analyses of single cases. We discuss the implications of these data for the motor theories of action and object recognition.

Method

Participants

Patients. A total of 37 consecutively admitted patients (mean age 63.9 ± 10.4 years; education 9.3 ± 3.9 years) took part in the study. Patients were recruited from the rehabilitation ward of the Ospedali Riuniti in Trieste. Only patients with focal unilateral brain lesions and no previous neurological history were included. Computed tomography (CT) or magnetic resonance imaging (MRI) scans were available for 35 patients. The lesions for those 35 patients were mapped using MRIcro software (www.mricro.com) onto a standard MRIcro template by a neuroradiologist (M.U.) who was unaware of the aims of the study. The Brodmann areas (see Appendix A) involved in the lesions have been identified using MRIcro software.

Controls. A total of 25 neurologically healthy individuals matched for age and education (mean age 66 ± 11 years; education 8.96 ± 4.1 years) with the patient group were recruited from patients' and staff's relatives, as well as from the rehabilitation ward of the Ospedali Riuniti in Trieste, where they were treated following orthopaedic surgery. They were administered the Edinburgh Handedness Questionnaire (Oldfield, 1971) and took part in the experimental session only if they were right-handed. They performed the object-related tasks described below with their dominant hand. A second group of control participants recruited on the basis of the same criteria ($N = 11$; right-handed, age 69.9 ± 6.85 years; education 10.4 ± 4.2 years) were tested on the action imitation task described below using their nondominant (i.e., left) hand. This was in order to have a suitable baseline with which to compare the performance of patients, who due to hemiparesis were not able to complete the tasks with their dominant hand. There were no differences (all ts < 1, independent samples) between the control groups, or the control groups and the patient groups, for either age or education.

The Revised Standardized Difference Test (RSDT) was computed to detect classical and strong dissociations, as suggested by Crawford and Garthwaite (2006), using the software released with the article by Crawford and Garthwaite (2005). Classical dissociations, in which a patient was impaired compared to controls on Task A, but within the normal range on Task B, were determined based on the significance values of the t scores, taking into account the correlation within controls across the two tasks. Strong dissociations, in which a patient was impaired on both Tasks A and B compared to controls, but relatively more impaired on Task A, were also determined with the RSDT method. Because a number of patients with apraxic deficits were not able to perform praxis tests with their dominant hand, we computed separate t scores for pantomime imitation based on the performance of the group of 11 controls who performed those tasks with their nondominant left hand. The pattern of findings for the pantomime imitation task remained the same regardless of which control group was used as the baseline (see Table 1 for all data).

Neuropsychological assessment

All 37 patients were administered a neuropsychological assessment evaluating language, praxis, visuo-spatial abilities, executive functions, and memory. They were tested in a quiet room in the hospital or at home. The neuropsychological results for all 37 patients are summarized in Appendix A.

Experimental study

In all experimental tasks, no feedback was provided to participants (patients or controls) about their performance (verbally or in any other way). The order of tasks was counterbalanced across participants, whereas the order of presentation of the items was fixed for the imitation tasks and randomized for the object use task. All patients and the group of 25 controls completed the following tasks, over the same set of 29 objects of common use (the complete set of stimuli is listed in Appendix B).

Object recognition. Patients and controls ($n = 25$) were asked to name the 29 objects (presented as coloured photographs). For each item, a participant's response was scored "0" if they were not able to name the object and "1" if they named the object correctly. Dialectal names were considered acceptable (i.e., scored as "1"). The maximum possible score was 29/29. Because the objective of the object-naming task was to determine whether the patients were able to recognize the object at a basic level, patients were allowed to self-correct after making phonological errors or dysfluencies. If the patient produced the correct name after having made a phonological error, the response was scored as correct. However, semantic paraphasias, even at the first attempt, were scored as errors. In place of the

Table 1. *Summary of performance of all patients across all experimental tasks*

	Object recognition		*Pantomime recognition*		*Object use*		*Pantomime imitation*			*Imitation of intransitive actions*		
Patient	*% correct*	*t* score	*% correct*	*t* score	*% correct*	*t* score	*% correct*	*t* score[a]	*t* score[b]	*% correct*	*t* score[a]	*t* score[b]
A.N.	100	0.49	100	1.04	100	0.83	80	0.23	0.58	90	0.77	0.33
B.A.	97	−1.97	100	1.04	89.5	−1.35	82.5	0.40	0.76	65	−1.20	−3.72
B.E.	90	−7.71	100	1.04	78.5	−3.65	72.5	−0.28	0.04	50	−2.39	−6.16
B.L.	100	0.49	83	−2.36	80.5	−3.22	10	−4.52	−4.46	35	−3.57	−8.59
B.O.	100	0.49	86	−1.76	100	0.83	87.5	0.77	1.12	88.6	0.68	0.13
B.R.	93	−5.24	93	−0.36	81	−3.13	70	−0.45	−0.14	65	−1.20	−3.72
C.A.	100	0.49	100	1.04	100	0.83	87	0.74	1.08	85	0.38	−0.48
C.E.	90	−7.71	97	0.44	93.5	−0.52	50	−1.89	−1.58	40	−3.18	−7.78
C.I.	100	0.49	90	−0.96	87	−1.88	60	−1.13	−0.86	77.5	−0.21	−1.67
C.S.	97	−1.97	97	0.44	86	−2.08	62.5	−1.00	−0.68	55	−1.99	−5.35
D.M.	93	−5.24	100	1.04	93	−0.62	77.5	0.06	0.40	70	−0.81	−2.91
D.P.	100	0.49	100	1.04	100	0.83	90	0.91	1.30	72.5	−0.61	−2.51
D.R.	96	−2.79	93	−0.36	80	−3.33	40	−2.48	−2.29	55	−1.99	−5.35
D.U.	100	0.49	96	0.24	96.5	0.10	87.5	0.77	1.12	67.5	−1.00	−3.32
F.G.	100	0.49	100	1.04	93	−0.62	70	−0.45	−0.14	72.5	−0.61	−2.51
F.L.	100	0.49	96	0.24	88	−1.67	60.5	−1.09	−0.82	63.3	−1.34	−4.01
F.S.	100	0.49	86	−1.76	50	−9.58	17.5	−4.01	−3.92	42.5	−2.98	−7.38
F.U.	100	0.49	100	1.04	100	0.83	100	1.59	2.02	100	1.56	1.96
G.O.	93	−5.25	86	−1.76	86.5	−1.88	67.5	−0.65	−0.32	72.5	−0.61	−2.51
M.A.	100	0.49	100	1.04	98.5	0.52	90	0.91	1.30	100	1.56	1.96
M.E.	100	0.49	100	1.04	95.5	−0.1	85	0.57	0.94	90	0.77	0.33
M.Z.	100	0.49	90	−0.96	90	−1.25	52.5	−1.64	−1.40	75	−0.41	−2.10
P.E.	100	0.49	93	−0.36	89.5	−1.35	70	−0.47	−0.14	80	−0.02	−1.29
P.I.	83	−13.44	79	−3.16	98.5	0.52	92.5	1.08	1.48	87.5	0.58	−0.07
P.N.	97	−1.97	100	1.04	94	−0.41	50	−1.89	−1.58	52.5	−2.19	−5.75
P.O.	100	0.49	100	1.04	98.5	0.52	87.5	0.77	1.12	95	1.17	1.14
P.T.	97	−1.97	93	−0.36	91	−1.04	27.5	−3.33	−3.20	35.6	−3.51	−8.47
R.O.	100	0.49	69	−5.16	58.5	−7.81	10	−4.52	−4.46	42.5	−2.98	−7.38
S.C.	90	−7.71	97	0.44	65	−6.46	50	−1.89	−1.58	45	−2.78	−6.97
S.O.	100	0.49	93	−0.36	100	0.83	70	−0.45	−0.14	95	1.17	1.14
S.R.	97	−1.97	72	−4.56	81.5	−3.02	52.5	−1.64	−1.40	65	−1.20	−3.72
S.T.	90	−7.71	72	−4.56	47.5	−10.1	27.5	−3.33	−3.20	45	−2.78	−6.97
S.V.	93	−5.25	90	−0.96	48	−10.0	30	−3.16	−3.02	40	−3.18	−7.78
T.O.	97	−1.97	100	1.04	98.5	0.52	85	0.60	0.94	82.5	0.18	−0.88
T.S.	100	0.49	100	1.04	100	0.83	82.5	0.42	0.76	85	0.38	−0.48
Z.A.	86	−10.98	86	−1.76	63	−6.88	42.5	−2.32	−2.12	42.5	−2.98	−7.38
Z.E.	100	0.49	100	1.04	96	0	85	0.60	0.72	70	−0.81	−2.91

Note: Patients are sorted alphabetically by their initials.
[a] 25 controls. [b] 11 controls.

naming task, patients with severe language impairments were administered a multiple-choice task in which three colour photographs were presented simultaneously, and the experimenter said aloud the name of the target photograph. Distractors were semantically related to the target (e.g., target: pen; distractors: eraser, scissors). The list of distractors for the multiple-choice test for object recognition (and pantomime recognition, see below) is reported in Appendix C.

Pantomime recognition. Patients and controls ($n = 25$) were asked to name 29 pantomimes (performed by the experimenter) of object use (with the object absent). Responses were scored as correct (1 point) if the patient named either the action (e.g., "hammering", "you are driving a nail") or the object involved in the action (e.g., "you are using a hammer"). Responses were scored as incorrect (0 points) if the participant did not correctly recognize the action. The maximum possible score was 29/29. Patients with severe language impairments completed a multiple-choice task in which they were asked to indicate the picture (out of three) depicting the action pantomimed by the experimenter. Distractors were semantically related photographs and, when possible, depicted an action visually similar to the target (e.g., target: brushing teeth; distractors: washing hands, shaving). The materials for the multiple-choice version of the pantomime recognition test are listed in Appendix C.

Imitation of pantomimes. All participants were asked to imitate the pantomimes corresponding to the same 29 objects demonstrated by the experimenter. The objects were not visible during this task. Performance was videotaped and was subsequently scored as follows: A total of 2 points were given if the action was correctly imitated, 1 point if the action was imitated with errors but still recognizable, and 0 points if the action was not recognizable. The maximum possible score was 58/58. One group of controls ($n = 25$) performed this task with the dominant right hand, while the other group of controls ($n = 11$) performed this task with their nondominant left hand.

Object use. Patients and controls ($n = 25$) were asked to demonstrate, with the object in hand, the use of the 29 objects. The same videotaping and scoring criteria were applied as those used in the imitation of pantomimes task (2 points were given if the object was used correctly, 1 point if the action was performed with errors but still recognizable, and 0 points if the action was not recognizable). The maximum possible score was 58/58.

Imitation of intransitive actions. All participants were asked to perform a separate imitation task, similar to that devised by De Renzi, Motti, and Nichelli (1980). This task involves the imitation of 20 intransitive actions (i.e., in which objects are not involved), including 10 meaningless (e.g., raising thumb and little finger) and 10 meaningful gestures (e.g., moving the index finger back and forward to signal for someone to come closer). Performance was videotaped and was then scored as described above: A total of 2 points were given if the action was correctly imitated, 1 point if the action was imitated with errors but still recognizable, and 0 points if the action was impossible to recognize. The maximum possible score was 40/40. One group of controls ($n = 25$) performed this task with the dominant right hand, while the other group of controls ($n = 11$) performed this task with their nondominant left hand.

Results

The performance of all patients on the praxis and recognition tasks using the same set of 29 objects is summarized in Table 1.

Correlational analyses

As noted in the Introduction, recent research (e.g., Buxbaum et al., 2005) has based inferences regarding the role of motor processes in action recognition on group level correlations observed in large numbers of patients. The logic of the present study is to consider whether in our group of unselected unilateral stroke patients, it is possible to reproduce the correlations that have previously been observed between the different praxis-related tasks that were administered. To that end, we computed Pearson's correlations between the four praxis tasks that were performed with the same set of 29 objects. These correlations were carried out over both t-scores and raw data and were essentially the same with both data sets (see Tables 2 and 3).

There were reliable and positive correlations between object use and pantomime recognition ($p < .001$; see Figure 1a), object use and object recognition ($p < .05$; see Figure 1b), and object use and pantomime imitation ($p < .001$). There

Table 2. *Results of the correlational analysis computed on the t scores*

	Pantomime recognition		*Object use*		*Pantomime imitation*	
	Pearson r	*N*	*Pearson r*	*N*	*Pearson r*	*N*
Object recognition	.271	37	.371*	37	.148	37
Pantomime recognition			.581**	37	.597**	37
Object use					.779**	37

*Correlation is significant at the .05 level (2-tailed). **Correlation is significant at the .001 level (2-tailed).

was a reliable and positive correlation between pantomime recognition and pantomime imitation ($p < .001$; see Figure 1c) but no reliable correlation between pantomime recognition and object recognition. There was also no reliable correlation between object recognition and pantomime imitation.

As discussed in the Introduction, the presence of correlations across tasks within a group of patients has served as the empirical basis for the inference that representations/processes involved in action production are required in order to recognize actions and objects. For instance, such inferences have been argued to follow from the observations (reported above) that performance in using objects is correlated with performance in recognizing objects, recognizing pantomimes, and imitating pantomimes. In the same vein, the correlation between pantomime recognition and pantomime imitation (reported above) reproduces the pattern observed by Buxbaum et al. (2005).

The mere presence of statistically significant correlations between performance across the group of patients on the different tasks does not, in and of itself, indicate that there is a relation between the abilities required to perform the tasks. However, the logic of demonstrating that such correlations can be obtained within the present group of patients is to show that this group of patients is comparable to those previously discussed (e.g., Buxbaum et al., 2005). In the next section we show that even though there are demonstrated correlations, at the single-case level the "abilities" that are correlated between tasks in fact clearly dissociate. In this sense, the multiple-single-case approach described below cannot be criticized as being drawn from an "atypical" group of patients.

Single-case dissociations

As discussed in the Introduction, a number of previous case studies have reported that impaired production of object-associated actions can be observed despite unimpaired (a) pantomime recognition and/or (b) object recognition. There have also been cases reported who are impaired at pantomime imitation but spared at pantomime recognition. Here we describe patients from this group who demonstrated these three dissociations. Table 4 provides a summary of those cases that are discussed in this multiple-single-case analysis.

Table 3. *Results of the correlational analysis computed on the raw scores*

	Pantomime recognition		*Object use*		*Pantomime imitation*	
	Pearson r	*N*	*Pearson r*	*N*	*Pearson r*	*N*
Object recognition	.271	37	.371*	37	.154	37
Pantomime recognition			.580**	37	.593**	37
Object use					.778**	37

*Correlation is significant at the .05 level (2-tailed). **Correlation is significant at the .001 level (2-tailed).

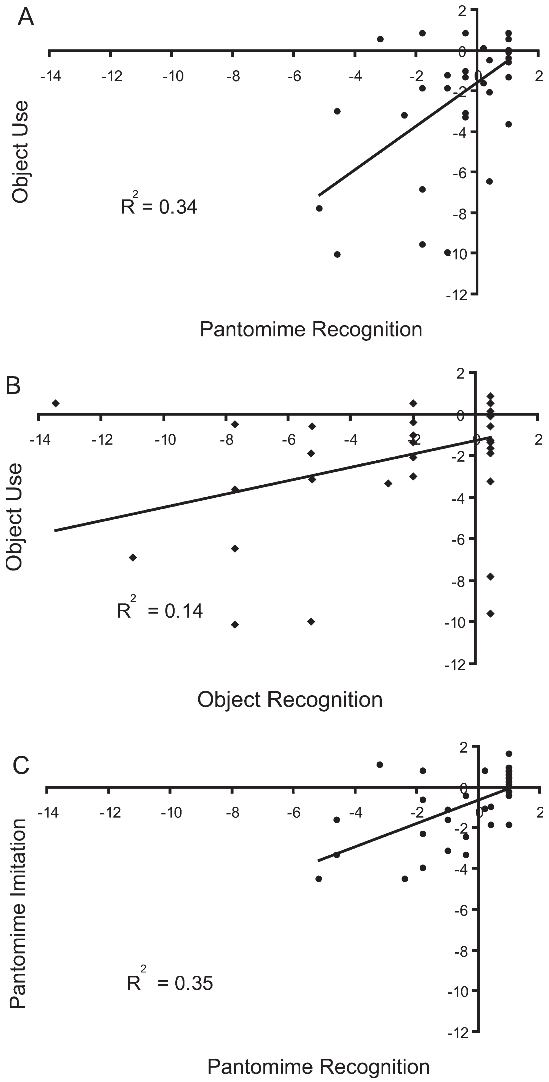

Figure 1. *Group level correlations in performance across tasks. A. The ability of patients to use a set of 29 objects was correlated (*p < *.001; Spearman's rho) with their ability to recognize the same object-associated actions when performed by the experimenter. B. The ability of the patients to use the same set of objects was correlated (*p < *.003) with their ability to recognize those objects. C. The ability of the patients to imitate the same set of object-associated actions was correlated (*p < *.001) with their ability to imitate the same actions.*

Impaired object use compared to pantomime recognition. As depicted in Figure 2a (see also Table 4), 6 patients (S.V., S.C., B.E., B.R., D.R., and C.S.) were impaired at using objects but within the normal range for recognizing object-associated pantomimes. This pattern was observed both in patients who were administered the naming version of the pantomime recognition test (B.E., C.S.) and in those who performed the multiple-choice version of the pantomime recognition task (S.C., S.V., D.R., B.R.). Of these 6 patients, 5 of them were impaired at recognizing objects (S.V., B.E., S.C., B.R., and D.R.) while C.S. was in the normal range for object recognition. Of the 6 patients, 2 were impaired for pantomime imitation (S.V. and D.R.) while the others were in the normal range. The imitation of intransitive actions was impaired in S.V., S.C., and B.E., but within normal limits for B.R., D.R., and C.S.

Another 4 patients (F.S., R.O., S.T., and Z.A.) presented with disproportionate deficits (i.e., strong dissociations) for using objects compared to recognizing pantomimes (see Figure 2a and Table 4). For these 4 patients, performance on both object use and recognizing pantomimes was outside of the control range. All 4 of these patients were impaired at imitating pantomimes as well as imitating intransitive actions. Patients F.S. and R.O. performed normally on the object recognition task, whereas S.T. and Z.A. were impaired in recognizing objects.

Impaired pantomime recognition compared to object use. Two patients (B.O. and P.I.) were able to use objects despite being impaired at recognizing the associated pantomimes. Both patients B.O. and P.I. were unimpaired for imitating pantomimes. P.I.'s deficit for pantomime recognition was associated with a deficit in recognizing objects (both recognition tasks performed with the multiple-choice versions of the tasks).[2] Interestingly, B.O. was in the normal range for object recognition. The observation of a selective

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[2] It is unlikely that P.I.'s impairment for recognizing the pantomimes can be explained by a general visual impairment, because the patient was within the normal range on the Visual Object and Space Perception Battery (VOSP) and object decision screening tests, ruling out at least some types of a general visual impairment (see Appendices A and C).

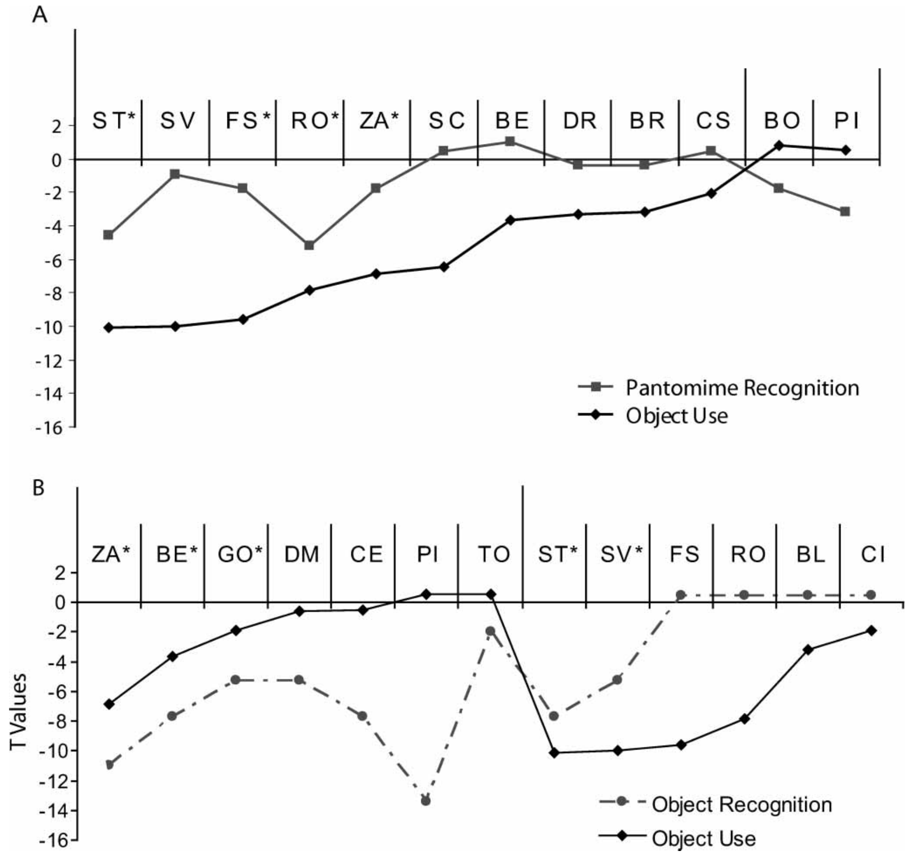

Figure 2. *Double dissociations between object use and pantomime recognition (A) and object use and object recognition (B). * Indicates strong (i.e., disproportionate) dissociations.*

impairment for recognizing pantomimes, termed *pantomime agnosia* (Rothi, Mack, & Heilman, 1986), suggests functionally dissociable processes for action and object recognition.

Impaired object use compared to object recognition. As depicted in Figure 2b, 4 patients (B.L., R.O., C.I., and F.S.) were impaired in using objects but were within the normal range for recognizing objects. Patients B.L., R.O., and F.S. were impaired for pantomime recognition, pantomime imitation, and imitation of intransitive actions, whereas C.I. was in the normal range for these tasks.

Two patients (S.T. and S.V.) presented with disproportionate impairments (i.e., strong dissociations) in using objects compared to object recognition. Both patients were also impaired for imitating pantomimes and intransitive actions. S.T. was impaired for recognizing pantomimes while S.V. was in the normal range.

Impaired object recognition compared to object use. In contrast, 4 patients (C.E., T.O., D.M., and P.I.) were impaired for object recognition but were within the normal range for using the same objects. Patients C.E., T.O., and D.M. were unimpaired for recognizing pantomimes, whereas P.I. was impaired in this task (using the multiple-choice version). These 4 patients performed within the normal range for imitating pantomimes, while only patient C.E. was impaired for imitating intransitive actions.

Table 4. *Simplified profile of patients discussed in the text*

	Patient initials	*Object recognition*	*Pantomime recognition*	*Object use*	*Pantomime imitation*	*Imitation of intransitive actions*
Impaired pantomime recognition compared to object use	S.V.	X$_{\text{MC}}$	√$_{\text{MC}}$	X	X	X
	S.C.	X$_{\text{MC}}$	√$_{\text{MC}}$	X	√	X
	B.E.	X	√	X	√	X
	B.R.	X$_{\text{MC}}$	√$_{\text{MC}}$	X	√	√
	D.R.	X$_{\text{MC}}$	√$_{\text{MC}}$	X	X	X
	C.S.	√	√	X	√	X
	F.S.[a]	√	X	X	X	X
	R.O.[a]	√$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
	S.T.[a]	X$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
	Z.A.[a]	X$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
Impaired object use compared to pantomime recognition	B.O.	√	X	√	√	√
	P.I.	X$_{\text{MC}}$	X$_{\text{MC}}$	√	√	√
Impaired object use compared to object recognition	B.L.	√$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
	R.O.	√$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
	C.I.	√	√	X	√	√
	F.S.	√	X	X	X	X
	S.T.[a]	X$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
	S.V.[a]	X$_{\text{MC}}$	√$_{\text{MC}}$	X	X	X
Impaired object recognition compared to object use	C.E.	X	√	√	√	X
	T.O.	X	√	√	√	√
	D.M.	X	√	√	√	√
	P.I.	X$_{\text{MC}}$	X$_{\text{MC}}$	√	√	√
	Z.A.[a]	X$_{\text{MC}}$	X$_{\text{MC}}$	X	X	X
Selectively impaired pantomime and action imitation	B.E.[a]	X	√	X	√	X
	G.O.[a]	X	X	X	√	√
	P.T.	√	√	√	X	X

Note: "√" indicates performance within the normal range; "X" indicates impaired performance compared to control participants ($n = 25$). The subscript "MC" indicates that the multiple-choice version of the task was completed by the patient.

A total of 3 patients (Z.A., B.E., G.O.) presented with disproportionate deficits (i.e., strong dissociations) for object recognition compared to object use. Patient B.E. was within the normal range for pantomime recognition while G.O. and Z.A. were impaired on this task. Patients B.E. and G.O. were within the normal range for imitating pantomimes, while Z.A. was impaired on this task. Patients Z.A. and B.E. were impaired for imitating intransitive actions, while patient G.O. was in the normal range.

Impaired pantomime imitation compared to pantomime recognition. As discussed above (see Figure 1; see also Buxbaum et al., 2005) we observed a reliable correlation between the ability of patients to imitate pantomimes and their ability to recognize object-associated pantomimes. However, contrary to this group level pattern, patient P.T. was impaired at imitating both object-associated actions and intransitive actions. Within the category of "intransitive" gestures, P.T. was equivalently impaired for meaningful and meaningless gestures (36.5% and 35% correct, respectively). However, P.T. was able to recognize object-associated pantomimes and was within the normal range in using and naming objects.

The pattern of performance of patient P.T. represents an important exception to the group level pattern. The performance of P.T. indicates that even if input axemes are "disconnected" from output axemes, it is still possible to successfully recognize pantomimes. Other studies have reported patients who are impaired at imitating meaningless gestures but still able to recognize gestures (L.K. and E.N.; Goldenberg & Hagmann, 1997; Cases 12 and 23 in Tessari et al., 2007; B.S., Bartolo et al., 2001; F.G., Rumiati et al., 2001).

GENERAL DISCUSSION

The objective of this study was to directly address a recent divergence in theoretical claims that have been made based on studies of apraxic patients. On the basis of single-case analyses, it has been argued that motor production processes associated with object use are not necessary in order for successful action or object recognition. On the basis of group level patterns, it has been argued that motor production processes involved in using objects are critically involved in recognizing those same objects and in recognizing and imitating object-associated pantomimes. The theoretical claims that have been developed on the basis of single-case analyses follow from dissociations in performance across tasks within the same patient. In contrast, the theoretical claims that have been developed on the basis of group level patterns are based on associations in performance across different tasks at the group level.

In order to address this divergence in theoretical claims we carried out analyses at both the group and the single-case level. We reproduced both the associations at the group level that have been previously reported and the dissociations at the single-case level that have been previously reported. At the group level, there were reliable correlations (see also Buxbaum et al., 2005) between pantomime recognition and pantomime imitation and between pantomime recognition and object use. These correlations have served as the basis for the argument from neuropsychological data that action production processes are constitutively involved in action recognition. However, within our group of patients, we also observed individual cases whose performance profiles are problematic for the motor theories of action and object recognition. First, patients were observed who were impaired for object use but relatively unimpaired for action recognition, as well as the reverse. Second, patients were observed who were impaired for object use but relatively unimpaired for object recognition, as well as the reverse. Third, one patient was observed who was impaired for imitating pantomimes, but was relatively unimpaired for recognizing pantomimes and using objects.

There is an asymmetry, within "neuropsychological evidence", between specific theoretical proposals and observations of associations versus dissociations of abilities. In the Introduction we described the IAM (independent axeme model) in which input and output axemes are functionally separable (see Rothi et al., 1991). This model can be contrasted with the motor theory of action recognition. Importantly, both the IAM and the motor theory of action recognition are consistent with the group level correlations that we and others (Buxbaum et al., 2005) have reported. On the other hand, the dissociations observed within single cases indicate that both object use and pantomime imitation can be impaired despite normal performance in pantomime and object recognition (for a similar discussion in the context of agrammatism, see Caramazza, Capasso, Capitani, & Miceli, 2005). These dissociations indicate the following: (a) The ability to use objects is not necessary in order to be able to recognize object-associated pantomimes; (b) the ability to imitate pantomimes is not necessary in order to be able to recognize object-associated pantomimes; and (c) the ability to use objects is not necessary in order to be able to recognize objects. This means that (a) output axemes and input axemes are functionally dissociable, and (b) that the integrity of output axemes is not necessary in order for the successful functioning of input axemes and object recognition processes. This conclusion means that we must reject the strong forms of the motor theories of action and object recognition. It is important to note that this conclusion does not mean that motor production processes may not modulate, or serve as important inputs to, object and action recognition processes (for discussion of object recognition processes, see Mahon et al., 2007).

The conclusion that motor production processes are not necessary in order to recognize objects and actions would seem to be at variance with the fact that brain structures subserving motor production are automatically activated when participants observe manipulable objects (for review, see Martin, 2007). For the remaining discussion, we consider more closely some possible roles of motor simulation in action and object recognition. In particular, we consider which of the individual assumptions that comprise the motor theories of action and object recognition may find empirical support.

What is the role of motor simulation in action and object recognition?

In the Introduction we introduced an operational definition of "motor simulation": Motor simulation refers to the automatic activation of motor production processes in the course of recognizing actions and objects. We chose this construal of the term "motor simulation" because it is theoretically neutral regarding whether or not the activation of motor production processes is necessary in order for successful recognition of actions and manipulable objects to occur. According to this construal, the motor theories of action and object recognition can each be decomposed into two separate assumptions. The first assumption, common to both hypotheses, is that observation of an action or a manipulable object automatically activates the motor system of the observer (for discussion of this "direct matching hypothesis" as it applies to the motor theory of action recognition, see Greenwald, 1970; Prinz, 1997; Rizzolatti et al., 2001). The second assumption shared by the motor theories of action and object recognition is that the activation of the motor system is required (read *necessary*) for successful recognition of actions and manipulable objects. The validity of drawing a distinction between these two theoretical assumptions obtains only in the measure to which substance can be given to the notion of "automatic" as opposed to "necessary" activation.

As reviewed in the Introduction, there is a wealth of empirical data supporting the view that the motor system is "automatically" engaged when observers view actions and manipulable objects. The motor theories of action and object recognition are theories about the ways in which stimuli are processed, in that they claim that motor-relevant information must be retrieved in order for successful recognition to occur. The neuropsychological data that have been reported and reviewed herein indicate that motor production processes are not necessary for successful recognition of either actions or objects. This conclusion sets in a new light the (undisputed) empirical fact that motor regions are automatically activated in tasks in which the retrieval of motor information is not necessary. In other words, the question is not: What role do motor production processes play in action and object recognition? A more basic question is: Why would there be activation of the motor system if that activation is not causally involved in the task?

To this point, discussions of the role of production processes in recognition have been very general (Buxbaum et al., 2005; Cubelli et al., 2000; Gallese & Lakoff, 2005; Helbig et al., 2006; Johnson-Frey, 2004; Kellenbach et al., 2003; Mahon & Caramazza, 2005; Martin et al., 2000; Pulvermüller, 2005; Rosci et al., 2003; Rothi et al., 1991). This generality respects our current knowledge in that it is not obvious how the term "recognition" should be fleshed out when discussing action and object recognition. The way in which the term "recognition" is deployed is not theory neutral, as it may entail various commitments about the nature of the information that is required in order to accurately recognize (i.e., categorize) objects for use and/or accurately identify objects for naming. One way in which we might be able to get some traction on this issue is by articulating the processes that are implicated by the term "recognition". How is it possible to observe a patient who is impaired at recognizing objects (e.g., for naming or conceptual judgements) but who can nevertheless use the objects correctly? Such dissociations suggest that the term "recognition" may fractionate into "recognition for use" and "recognition for naming/conceptual access".

Previous authors have proposed the IAM (Cubelli et al., 2000; Rothi et al., 1991) in which separate processes mediate action production, action recognition, and object recognition. Left unspecified, however, this model is not satisfactory in that it provides no explanation of the fact that the motor system (e.g., output axemes) is activated in tasks in which such activation would not apparently be required. For instance, naming pictures of manipulable objects differentially activates premotor and posterior parietal structures (e.g., Martin & Chao, 2001). However, the single-case analyses suggest that such activation is not necessary. The IAM, in its strongest "disembodied" form, provides no natural explanation of why there would be such activation. A further assumption would have to be made in order to explain why motor production processes are activated in task-irrelevant situations when observers view actions or manipulable objects. On this model, such motor activation would be taken to be informative of the dynamics of activation flow throughout the system (for other considerations along these lines, see Mahon & Caramazza, 2007).

For discussion, let us assume some set of assumptions [x] regarding the dynamics of activation flow throughout the cognitive system that collectively explain the activation of motor processes when observers view actions and manipulable objects. Even so, the ultimate reason for such an architecture would remain unresolved: It would remain unaddressed what purpose is served by such "automatic" spreading of activation. One possibility is that the automatic activation of the motor system may serve the function of keeping the organism in a state of readiness vis-à-vis its immediate environment. An alternative, and not mutually exclusive function, may concern feedback loops from motor processes to perceptual and conceptual processing (see Mahon et al., 2007, for discussion). In other words, it may be the case that motor information shapes the way in which non-motor-relevant information is processed in the system. It remains an open issue as to whether activation of motor information facilitates normal action and object recognition. We can now address this question with clear constraints on what might be implied by such facilitation, given the strong evidence provided by neuropsychological data, neurophysiological data, and functional-neuroimaging data.

Alternatively, it might be argued from a strong embodied cognition perspective, that these neuropsychological data are not relevant to the embodied cognition hypothesis—that only activation evidence is relevant. This line of argument, however, does not go through. In the measure to which the activation evidence is taken as evidence for the embodied cognition hypothesis, then the neuropsychological data are problematic for that hypothesis. If the embodied cognition hypothesis were to be changed in such a way that the neuropsychological data were no longer relevant to that hypothesis, then one would have to reconsider what the activation evidence implies about the dynamics of information retrieval within the sensory/motor systems.

On the basis of the evidence available to date, it cannot be decided whether the automatic activation of motor information (i.e., motor simulation) contributes to the richness of conceptual experience. For instance, while the data we have reported from single-case analyses indicate that output processes are not necessary for successful recognition, it remains an open question as to whether patients who have impaired output axemes have, on some level, impoverished concepts of actions and manipulable objects. To this point, the associations at the group level and the dissociations at the single-case level that have been observed in neuropsychological studies permit a model of praxis to be outlined in its basic features. An important issue that merits further research involves fleshing out the processes and content contained within the putative input systems that mediate action and object recognition.

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REFERENCES

Adolphs, R. (2003). Cognitive neuroscience of human social behaviour. *Nature Reviews Neuroscience*, *4*, 165–178.

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

Aziz-Zadeh, L., Maeda, F., Zaidel, E., Mazziotta, J., & Iacoboni, M. (2002). Lateralization in motor facilitation during action observation: A TMS study. *Experimental Brain Research*, *144*, 127–131.

Baldissera, F., Cavallari, P., Craighero, L., & Fadiga, L. (2001). Modulation of spinal excitability during observation of hand actions in humans. *European Journal of Neuroscience*, *13*, 190–194.

Bartolo, A., Cubelli, R., Della Sala, S., Drei, S., & Marchetti, C. (2001). Double dissociation between meaningful and meaningless gesture reproduction in apraxia. *Cortex*, *37*, 696–699.

Bergego, C., Pradat-Diehl, P., & Deloche, G. (1992). Apraxie idéatorie et reconnaissance de l'utilisation des objets. *Revue de Neuropsychologie*, *2*, 193–206.

Buccino, G., Lui, F., Canessa, N., Patteri, I., Lagravinese, G., Benuzzi, F., et al. (2004). Neural circuits involved in the recognition of actions performed by non-conspecifics: An fMRI study. *Journal of Cognitive Neuroscience*, *16*, 114–126.

Buxbaum, L. J., Kyle, K. M., & Menon, R. (2005). On beyond mirror neurons: Internal representations subserving imitation and recognition of skilled object-related actions in humans. *Cognitive Brain Research*, *25*, 226–239.

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

Buxbaum, L. J., Schwartz, M. F., & Carew, T. G. (1997). The role of semantic memory in object use. *Cognitive Neuropsychology*, *14*, 219–254.

Buxbaum, L. J., Sirigu, A., Schwartz, M. F., & Klatzky, R. (2003). Cognitive representations of hand posture in ideomotor apraxia. *Neuropsychologia*, *41*, 1091–1113.

Buxbaum, L. J., Veramonti, T., & Schwartz, M. F. (2000). Function and manipulation tool knowledge in apraxia: Knowing "what for" but not "how." *Neurocase*, *6*, 83–97.

Caffarra, P., Vezzadini, G., Dieci, F., Zonato, F., & Venneri, A. (2004). Modified Card Sorting Test: Normative data. *Journal of Clinical and Experimental Neuropsychology*, *26*, 246–250.

Caramazza, A., Capasso, R., Capitani, E., & Miceli, G. (2005). Patterns of comprehension performance in agrammatic Broca's aphasia: A test of the trace deletion hypothesis. *Brain and Language*, *94*, 43–53.

Carlesimo, G. A., Caltagirone, C., & Gainotti, G. (1996). The Mental Deterioration Battery: Normative data, diagnostic reliability and qualitative analyses of cognitive impairment. *European Neurology*, *36*, 1996.

Chao, L. L., & Martin, A. (1999). Cortical regions associated with perceiving, naming, and knowing about colours. *Journal of Cognitive Neuroscience*, *11*, 25–35.

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. (2006). Methods of testing for a deficit in single case studies: Evaluation of statistical power by Monte Carlo simulation. *Cognitive Neuropsychology*, *23*, 877–904.

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

De Renzi, E., & Lucchelli, F. (1988). Ideational apraxia. *Brain*, *111*, 1173–1185.

De Renzi, E., Motti, F., & Nichelli, P. (1980). Imitating gestures: A quantitative approach to ideomotor apraxia. *Archives of Neurology*, *37*, 6–10.

Dumont, C., & Ska, B. (2000). Pantomime recognition impairment in Alzheimer's disease. *Brain and Cognition*, *43*, 177–181.

Dumont, C., Ska, B., & Schiavetto, A. (1999). Selective impairment of transitive gestures: An unusual case of apraxia. *Neurocase*, *5*, 447–458.

Fadiga, L., Craighero, L., Buccino, G., & Rizzolatti, G. (2002). Speech listening specifically modulates the excitability of tongue muscles: A TMS study. *European Journal of Neuroscience*, *15*, 399–402.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, *73*, 2608–2611.

Fogassi, L., Ferrari, P. F., Gesierich, B., Rozzi, S., Chersi, F., & Rizzolatti, G. (2005). Parietal lobe: From action organization to intention understanding. *Science*, *308*, 662–667.

Gallese, V. (2005). Embodied simulation: From neurons to phenomenal experience. *Phenomenology and the Cognitive Sciences*, *4*, 23–48.

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*, 593–609.

Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind reading. *Trends in Cognitive Sciences*, *2*, 493–501.

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

Giovagnoli, A. R., Del Pesce, M., Mascheroni, S., Simoncelli, M., Laiacona, M., & Capitani, E. (1996). Trail making test: Normative values from 287 normal adult controls. *The Italian Journal of Neurological Sciences*, *17*, 305–309.

Goldenberg, G., & Hagmann, S. (1997). The meaning of meaningless gestures: A study of visuo-imitative apraxia. *Neuropsychologia*, *35*, 333–341.

Greenwald, A. G. (1970). Sensory feedback mechanisms in performance control: With special reference to the ideo-motor mechanism. *Psychological Review*, *77*, 73–99.

Halsband, U., Schmitt, J., Weyers, M., Binkofski, F., Grützner, G., & Freund, H. J. (2001). Recognition and imitation of pantomimed motor acts after unilateral parietal and premotor lesions: A perspective on apraxia. *Neuropsychologia*, *39*, 200–216.

Helbig, H. B., Graf, M., & Kiefer, M. (2006). The role of action representations in visual object recognition. *Experimental Brain Research*, *174*, 221–228.

Hodges, J. R., Bozeat, S., Lambon Ralph, M. A., Patterson, K., & Spatt, J. (2000). The role of conceptual knowledge in object use. Evidence from semantic dementia. *Brain*, *123*, 1913–1925.

Hodges, J. R., Spatt, J., & Patterson, K. (1999). "What" and "how": Evidence for the dissociation of object knowledge and mechanical problem-solving skills in the human brain. *Proceedings of the National Academy of Sciences*, *USA*, *96*, 9444–9448.

Howard, D., & Patterson, K. E. (1992). *The Pyramids and Palm Trees Test*. Bury St. Edmunds, UK: Thames Valley Test Co.

Johnson-Frey, S. H. (2004). The neural basis of complex tool use in humans. *Trends in Cognitive Sciences*, *8*, 71–78.

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*, 20–46.

Lauro-Grotto, R., Piccini, C., & Shallice, T. (1997). Modality-specific operations in semantic dementia. *Cortex*, *33*, 593–622.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review*, *74*, 431–461.

Liepmann, H. (1920). Apraxie [Apraxia]. *Ergebnisse der Gesamten Medizin*, *1*, 516–543.

Luzzatti, C. Willmes, K., & De Bleser, R. (1996). Aachener Aphasie Test: Versione Italiana [Aachener Aphasia Test (AAT): Italian Version]. Firenze: Organizzazioni Speciali.

Maeda, F., Kleiner-Fisman, G., & Pascual-Leone, A. (2002). Motor facilitation while observing hand actions: Specificity of the effect and role of observer's orientation. *Journal of Neurophysiology*, *87*, 1329–1335.

Mahon, B. Z., & Caramazza, A. (2005). The orchestration of the sensory-motor systems: Clues from neuropsychology. *Cognitive Neuropsychology*, *22*, 480–494.

Mahon, B. Z., & Caramazza, A. (2007). *Sensory-motor simulation and the grounding of conceptual content: The ghost in the motor system. Manuscript submitted for publication.*

Mahon, B. Z., Milleville, S., Negri, G. A., Rumiati, R. I., Caramazza, A., & Martin, A. (2007). Action-related properties shape object representations in the ventral stream. *Neuron*, *55*, 507–520.

Martin, A. (2007). The representation of object concepts in the brain. *Annual Review of Psychology*, *58*, 25–45.

Martin, A., & Chao, L. L. (2001). Semantic memory and the brain: Structure and processes. *Current Opinion in Neurobiology (Cognitive Neuroscience)*, *11*, 194–201.

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*. Cambridge, MA: The MIT Press.

Montomura, N., & Yamadori, A. (1994). A case of ideational apraxia with impairment of object use and preservation of object pantomime. *Cortex*, *30*, 167–170.

Moreaud, O., Charnallet, A., & Pellat, J. (1998). Identification without manipulation: A study of the relations between object use and semantic memory. *Neuropsychologia*, *36*, 1295–1301.

Mozaz, M., Rothi, L. J. G., Anderson, J. M., Crucian, G. P., & Heilman, K. M. (2002). Postural knowledge of transitive and pantomimes and intransitive gestures. *Journal of the International Neuropsychological Society*, *8*, 958–962.

MRIcro software: www.mricro.com

Negri, G. A. L., Lunardelli, A., Gigli, G. L., & Rumiati, R. I. (2007). Degraded semantic knowledge and accurate object use. *Cortex*, *43*, 376–388.

Ochipa, C., Rothi, L. J. G., & Heilman, K. M. (1989). Ideational apraxia: A deficit in tool selection and use. *Annals of Neurology*, *25*, 190–193.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*, 97–113.

Pick, A. (1905). *Studien über Motorische Apraxie und ihre Nahestehende Erscheinungen: Ihre Bedeutung in der Symptomatologie Psychopathologischer Symptomenkomplexe.* [Studies of motor apraxia and related manifestations: Their role in symptomatology of psychopathological symptom complexes.] Leipzig, Germany: Deuticke.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology*, *9*, 129–154.

Pulvermüller, F. (2005). Brain mechanisms linking language and action. *Nature Reviews Neuroscience*, *6*, 576–582.

Rapcsak, S. Z., Ochipa, C., Anderson, K. C., & Poizner, H. (1995). Progressive ideomotor apraxia: Evidence for a selective impairment of the action production system. *Brain and Cognition*, *27*, 213–236.

Rey, A. (1964). *L'examen clinique en psychologie* [The clinical exam in psychology.]. Paris: Presses Universitaires de France.

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.

Rizzolatti, G., & Wolpert, D. M. (2005). Motor systems. *Current Opinion in Neurobiology*, *15*, 623–625.

Rosci, C., Valentina, C., 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., Mack, L., & Heilman, K. M. (1986). Pantomime agnosia. *Journal of Neurology, Neurosurgery, and Psychiatry*, *49*, 451–454.

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

Rumiati, R. I., Zanini, S., Vorano, L., & Shallice, T. (2001). A form of ideational apraxia as a selective deficit of contention scheduling. *Cognitive Neuropsychology*, *18*, 617–642.

Schwartz, M. F., Montgomery, M. W., Fitzpatrick-DeSalme, E. J., Ochipa, C., Coslett, H. B., & Mayer, N. H. (1995). Analysis of a disorder of everyday action. *Cognitive Neuropsychology*, *12*, 863–892.

Shiffrar, M., & Freyd, J. J. (1990). Apparent motion of the human body. *Psychological Science*, *1*, 257–264.

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

Spinnler, H., & Tognoni, G. (1987). Standardizzazione e taratura italiana di test neuropsicologici. [Italian standardization and validation neuropsychological tests.] *Italian Journal of Neurological Sciences*, *6*, suppl. 8, 1–20.

Tessari, A., Canessa, N., Ukmar, M., & Rumiati, R. I. (2007). Neuropsychological evidence for a strategic control of multiple routes in imitation. *Brain*, *130*, 1111–1126.

Viviani, P., & Stucchi, N. (1989). The effect of movement velocity on form perception: Geometric illusions in dynamic displays. *Perception and Psychophysics*, *46*, 266–274.

Warrington, E. K. (1996). *The Camden memory test*. Hove, UK: Psychology Press.

Warrington, E. K., & James, M. (1991). *The Visual Object and Space Perception Battery.* Bury St Edmunds, UK: Thames Valley Test Company.

APPENDIX A

Results of the neuropsychological evaluation for all patients

Part 1

Patient initials	*Sex*	*Age*	*Education (years)*	*Testing post onset (months)*	*Oldfield*	*IMA*	*IA*	*AAT token*	*AAT rep*	*AAT write*	*AAT read*	*AAT name*	*AAT oc*	*AAT wc*	*Raven's CPM*	*VOSP screen*	*VOSP o.d.*	*Span fwd*	*Span bwd*	*Corsi*
A.N.	F	48	11	2	100	70	14	0	148	90	–	120	60	60	33	18	19	6	6	5
B.A.	M	70	13	2	42	61	14	27	114	25	–	60	33	0	12	15	8	4	2	4
B.L.	M	68	3	6	100	46	14	23	130	n.a.	24	108	49	47	14	20	17	3	p.u.	3
B.E.	M	65	8	2	83	58	12	15	134	78	–	109	51	48	19	20	12	3	3	4
B.O.	M	78	13	3	100	71	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	21	19	18	8	5	5
B.R.	M	58	11	3	100	53	14	48	39	12	–	0	41	0	36	20	16	n.a.	n.a.	5
C.A.	M	58	8	2	100	68	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	21	20	16	4	3	4
C.S.	M	76	12	1	83	65	13	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	22	19	13	4	4	5
C.E.	M	61	5	2	100	51	13	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	11	10	6	6	3	3
C.I.	M	70	8	1	-83	63	14	4	140	85	–	108	51	54	24	20	13	4	3	3
D.M.	F	68	5	1	100	68	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	18	20	13	5	2	3
D.P.	F	73	5	1	100	62	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	20	20	15	5	3	4
D.U.	M	72	5	2	100	53	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	25	18	17	4	2	4
D.R.	M	55	15	72	100	54	8	1	94	15	–	69	60	35	34	20	19	4	n.a.	5
F.L.	F	61	8	1	100	62	12	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	33	20	19	7	5	5
F.G.	M	50	13	60	100	60	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	29	20	19	4	4	5
F.U.	M	62	18	2	67	60	14	3	142	88	–	120	58	59	24	20	15	6	4	4
F.S.	F	55	9	2	100	52	14	13	133	82	–	109	60	57	29	19	16	5	3	4
G.O.	F	78	4	1	92	59	13	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	15	20	18	4	2	4
M.A.	M	60	13	2	100	67	14	4	131	84	–	119	58	60	34	20	15	5	4	5
M.Z.	M	81	13	2	100	65	12	1	125	85	–	110	55	56	27	20	20	6	4	4
M.E.	M	55	14	1	100	66	14	15	123	75	–	110	51	51	28	18	18	4	3	5
P.E.	F	43	8	2	83	63	14	1	131	88	–	115	49	52	23	19	17	4	3	4
P.T.	F	66	8	1	100	51	12	20	141	57	–	102	50	39	21	20	18	5	2	3
P.I.	F	65	8	2	100	58	14	31	96	55	–	29	44	43	26	18	16	2	3	4
P.O.	F	50	8	2	100	68	13	n.a.	148	n.a.	30	n.a.	59	n.a.	30	20	19	5	4	5
P.N.	F	63	5	2	83	65	13	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	21	20	18	4	3	2
R.O.	F	80	5	3	100	43	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	22	18	16	4	2	4
S.R.	F	69	8	1	100	54	11	39	147	29	–	67	47	40	24	20	13	4	2	3
S.C.	F	82	5	1	100	55	11	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	16	17	13	5	2	4
S.O.	M	70	11	1	100	69	14	2	149	89	–	114	58	60	32	20	18	5	4	5
S.V.	F	50	10	2	100	50	11	37	97	18	–	10	45	27	17	19	17	3	n.a.	4
S.T.	M	63	5	2	100	53	14	21	73	25	–	0	48	16	29	19	16	n.a.	n.a.	5
T.O.	M	67	13	6	100	51	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	n.a.	18	8	5	4	3
T.S.	M	66	15	2	100	70	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	25	18	19	6	4	3
Z.A.	M	40	18	2	83	49	10	47	1	0	–	0	37	31	26	20	17	p.u.	p.u.	4
Z.E.	F	65	5	2	100	62	14	n.a.	n.a.	n.a.	–	n.a.	n.a.	n.a.	20	20	20	4	4	4

Part 2

INITIALS	*P&P words*	*P&P pictures*	*TMT A*	*TMT B*	*TMT B-A*	*WEIGL*	*WCST N.cat*	*WCST pers*	*REY imm.*	*REY del.*	*REY rec.*	*WARR. faces*	*naming*	*Hemisph*	*Description of Lesion Numbers indicate Brodmann Areas*
A.N.	n.a.	50	33	63	30	n.a.	5	6	35	6	26/32	n.a.	30/30	L	11
B.A.	n.a.	50	p.u.	p.u.	p.u.	n.a.	6	4	p.u.	p.u.	p.u.	15	7/30	L	17,18,19,21,22,23,37,39, 40,41
B.L.	n.a.	49	113	407	294	3	n.a.	n.a.	27	8	29/32	n.a.	28/30	L	43,48
B.E.	n.a.	48	203	p.u.	p.u.	7	n.a.	n.a.	18	2	38/46	n.a.	29/30	L	48
B.O.	n.a.	52	197	p.u.	p.u.	13	6	2	29	4	27/32	n.a.	26/30	R	11,38,39,44,45,47,48
B.R.	n.a.	48	50	p.u.	p.u.	p.u.	p.u.	p.u.	n.a.	n.a.	n.a.	n.a.	0/30	L	20,21,22,37,38,39,42,48
C.A.	n.a.	51	70	388	318	9	3	1	37	8	43/46	n.a.	27/30	R	6,44,48
C.S.	n.a.	51	300	460	160	n.a.	6	2	35	6	30/32	n.a.	27/30	R	2,3,20,21,22,36,37,38,39, 40,41,42,43,47,48
C.E.	49	n.a.	p.u.	p.u.	p.u.	n.a.	4	5	25	7	27/32	n.a.	21/30	R	48
C.I.	n.a.	44	90	p.u.	p.u.	6	p.u.	p.u.	17	2	26/32	n.a.	29/30	L	7,18,19,21,22,37,39,40,41
D.M.	n.a.	50	142	530	388	n.a.	6	3	25	4	28/32	n.a.	26/30	R	48
D.P.	n.a.	n.a.	51	360	309	10	n.a.	n.a.	22	4	45/46	24	27/30	L	48
D.U.	n.a.	50	72	525	453	9	1	10	25	3	34/46	n.a.	27/30	R	42,48
D.R.	n.a.	51	n.a.	n.a.	n.a.	n.a.	6	1	p.u.	p.u.	p.u.	19	21/30	L	2,3,4,6,8,9,10,11,20,21, 22,37, 38,39,40,41,42, 43,44,45,46,47,48
F.L.	n.a.	52	41	142	101	n.a.	4	10	45	5	44/46	n.a.	20/20	L	inferior parietal lobe (no scan available)
F.G.	n.a.	52	125	p.u.	p.u.	n.a.	2	3	25	1	40/46	n.a.	19/20	L	2,3,4,5,6,7,17,18,19,20, 21,23,37,39,40,41
F.U.	n.a.	50	46	129	83	12	n.a.	n.a.	45	10	31/32	n.a.	29/30	L	10,45,46,47,48
F.S.	n.a.	51	78	324	246	n.a.	4	15	15	0	25/32	n.a.	25/30	L	Basal ganglia
G.O.	n.a.	49	79	371	292	n.a.	3	4	30	6	27/32	n.a.	27/30	R	6,44,45,46,48
M.A.	n.a.	52	32	142	110	10	n.a.	n.a.	38	8	29/32	n.a.	30/30	L	48
M.Z.	n.a.	51	152	238	86	n.a.	2	11	n.a.	n.a.	n.a.	20	30/30	L	nucleus lenticularis (no scan available)
M.E.	n.a.	51	35	217	182	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	29/30	L	22,43,48
P.E.	n.a.	n.a.	166	235	69	10	3	7	50	14	45/46	n.a.	28/30	R	Subcortical
P.T.	n.a.	50	211	p.u.	p.u.	6	n.a.	n.a.	21	1	28/32	n.a.	27/30	L	7,19,39,40
P.I.	n.a.	48	n.a.	n.a.	n.a.	9	5	2	n.a.	n.a.	n.a.	n.a.	2/30	L	20,21,22,37,38
P.O.	n.a.	51	30	80	50	n.a.	3	12	37	11	44/46	n.a.	29/30	R	20,21,22,37,39,41,42
P.N.	n.a.	51	198	p.u.	p.u.	n.a.	6	3	40	9	30	n.a.	26/30	R	3,6,7,40
R.O.	n.a.	n.a.	76	p.u.	p.u.	n.a.	n.a.	n.a.	30	5	41/46	n.a.	n.a.	L	21,22,41,42
S.R.	n.a.	46	n.a.	n.a.	n.a.	3	3	9	n.a.	n.a.	n.a.	23	17/30	L	Subcortical
S.C.	n.a.	52	197	p.u.	p.u.	5	p.u.	p.u.	38	8	29/32	n.a.	28/30	R	2,40,41,42
S.O.	n.a.	52	42	215	173	8	2	5	24	1	18/32	n.a.	29/30	L	20,41
S.V.	n.a.	47	n.a.	n.a.	n.a.	n.a.	6	3	n.a.	n.a.	n.a.	24	3/30	L	21,22,37,38,39,41,48
S.T.	n.a.	49	n.a.	n.a.	n.a.	10	2	5	n.a.	n.a.	n.a.	n.a.	0/30	L	2,3,4,38,47,48

(*Continued overleaf*)

Appendix A Continued

INITIALS	*P&P words*	*P&P pictures*	*TMT A*	*TMT B*	*TMT B-A*	*WEIGL*	*WCST N.cat*	*WCST pers*	*REY imm.*	*REY del.*	*REY rec.*	*WARR. faces*	*naming*	*Hemisph*	*Description of Lesion Numbers indicate Brodmann Areas*
T.O.	50	47	197	p.u.	p.u.	11	3	7	43	6	n.a.	n.a.	30/30	R	6,20,21,22,37,38,39,41, 42,43,44,45,48
T.S.	n.a.	51	62	300	238	10	6	0	33	7	44/46	n.a.	29/30	R	47,48
Z.A.	n.a.	50	56	410	354	n.a.	5	7	p.u.	p.u.	p.u.	13	p.u.	L	6,22,40,41,42,44,45,47,48
Z.E.	n.a.	52	62	213	151	5	3	2	43	8	30/32	n.a.	29/30	R	Subcortical

Note: F = female. M = male. Abbreviations used in the neuropsychological assessment: Oldfield = Oldfield (1971); IMA = Ideomotor Apraxia (De Renzi, Motti, & Nichelli, 1980); IA = Ideational Apraxia (De Renzi & Lucchelli, 1988); AAT = Aaachener Aphasie Test, Italian norms (Luzzatti, Willmes, De Bleser. Firenze, Organizzazioni Speciali, 1996); AAT token = token subtest; AAT rep = repetition; AAT writ = written language; AAT read = shortened version of the reading task with 30 items; AAT name = naming; AAT oc = oral comprehension; AAT wc = written comprehension; Raven's CPM: Raven Coloured Progressive Matrices (Carlesimo, Caltagirone, & Gainotti, 1996); VOSP = Visual Object and Space Perception battery (Warrington & James, 1991). VOSP screen = screening task; VOSP o.d. = object decision task; Span fwd = digit span forward; Span bwd = digit span backward; Corsi = Corsi test, spatial short-term memory (Spinnler & Tognoni, 1987); p.u. = patient unable to complete the task.

APPENDIX B

List of the experimental stimuli in alphabetical order

1. Bottle
2. Cigarette
3. Coffee mug
4. Comb
5. Duster
6. Eraser
7. Fork
8. Glass
9. Gun
10. Hammer
11. Iron
12. Jug
13. Key
14. Knife
15. Ladle
16. Lemon squeezer
17. Light bulb
18. Lipstick
19. Match
20. Paintbrush
21. Pen
22. Razor
23. Saw
24. Scissors
25. Screwdriver
26. Spanner
27. Spoon
28. Tennis racket
29. Toothbrush

APPENDIX C

List of distractors in the multiple-choice tasks

Target items are in capital letters.

Object recognition		
PEN	Eraser	Scissors
LIPSTICK	Razor	Comb
Pen	SCISSORS	Eraser
Screwdriver	Saw	PAINTBRUSH
Spoon	carafe	COFFEE MUG
Spanner	Screwdriver	KEY
Coffee mug	Spoon	CARAFE
Hammer	Light bulb	CIGARETTE
Eraser	Pen	Scissors
Saw	Hammer	GUN
Spanner	SCREWDRIVER	Hammer
SAW	Scissors	Paintbrush
Spanner	HAMMER	Screwdriver
Coffee mug	LEMON SQUEEZER	Carafe
IRON	Light bulb	Carafe
Comb	Lipstick	RAZOR
Pen	LIGHT BULB	Scissors
Hammer	SPANNER	Screwdriver
SPOON	Coffee mug	Carafe
Razor	COMB	Lipstick
Spoon	LADLE	Whisk
Carafe	Glass	BOTTLE
TOOTHBRUSH	Razor	Hairbrush
Spoon	Carafe	GLASS
MATCHSTICK	Lighter	Candle
Baseball bat	Table tennis bat	TENNIS RACKET
FORK	Coffee mug	Spoon
Scissors	Saw	KNIFE
Vacuum cleaner	sponge	CLOTH
Pantomime recognition		
WRITING WITH PEN	Writing with keyboard	Cutting with scissors
Applying nail polish	Using a nail file	APPLYING LIPSTICK
Knitting	Sewing	CUTTING WITH SCISSORS
Turning a spanner	PAINTING A WALL	Turning a screwdriver
DRINKING FROM COFFEE MUG	Pouring from a carafe	Eating with a spoon
Turning a tap	Opening a door handle	TURNING A KEY
POURING FROM A CARAFE	Beating a pestle in the mortar	Squeezing an orange
Applying eyeshadow	SMOKING A CIGARETTE	Shaving with a razor
Drawing with pencil	RUBBING WITH ERASER	Cutting with scissors
Using hairdryer	Using a spray	SHOOTING WITH A GUN
TURNING A SCREWDRIVER	Hammering	Using a chisel
Turning a spanner	SAWING	Using a chisel
Planing wood	HAMMERING	Cutting with an axe
SQUEEZING AN ORANGE	Eating pasta	Opening a bottle with a corkscrew
Vacuuming	IRONING	Knitting
Washing hands	Brushing teeth	SHAVING WITH A RAZOR
Turning a screwdriver	Using pliers	TURNING A LIGHT BULB
TURNING A SPANNER	Drilling	Sawing
Using a whisk	EATING WITH A SPOON	Drinking a cup of coffee
Applying makeup	COMBING HAIR	Drying hair
Vacuuming	Cleaning dishes with a sponge	CLEANING WINDOW WITH A CLOTH
Playing table tennis	Playing baseball	PLAYING TENNIS
Sawing	CUTTING WITH A KNIFE	Cutting with scissors
BRUSHING TEETH	Shaving with a razor	Combing hair
STIRRING WITH A LADLE	Stirring with a whisk	Eating with a spoon
Pouring from a carafe	DRINKING FROM A GLASS	Drinking from a coffee mug
Using a lighter	Lighting a candle	STRIKING A MATCH
Drinking from a glass	Pouring from a carafe	POURING FROM A BOTTLE
Eating with a spoon	Drinking from a coffee mug	EATING WITH A FORK