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Conceptual apraxia and semantic memory deficit in Alzheimer's disease: Two sides of the same coin?

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Abstract

This study was designed to examine the patterns of apraxic disturbances and the relationships between action knowledge and other measures of semantic knowledge about objects in 10 well-characterized Alzheimer's disease (AD) patients. Five tasks were used to assess components of action knowledge (action–tool relationships, pantomime recognition, and sequential organization of action) and praxis execution (actual use, pantomiming) according to the cognitive model of praxis. Three tasks (verbal comprehension, naming, and a visual semantic matching task) were used to assess verbal–visual semantics. Considering patterns of apraxia first, conceptual apraxia was found in 9 out of the 10 AD patients, suggesting that it is a common feature even in the early stages of AD. Second, we found partly parallel deficits in tests of action-semantic and verbal–visual semantic knowledge in 9 AD patients. Impaired action knowledge was found only in patients with a semantic language deficit. These findings provide no evidence that "action semantics" may be separated from other semantic information. Our results support the view of a unitary semantic system, given that the representations of action-semantic and other semantic knowledge of objects are often simultaneously disrupted in AD. (*JINS*, 2000, *6*, 693–703.)

Keywords: Conceptual apraxia, Semantic memory, Alzheimer's disease

INTRODUCTION

Limb apraxia is traditionally defined as a disorder of learned skilled movement that cannot be explained by an elemental motor deficit, intellectual deterioration, lack of understanding, or uncooperativeness (Heilman & Rothi, 1994). It may constitute one of the clinical signs of Alzheimer's disease (AD), as exemplified in the seminal paper by Alois Alzheimer (1907/1977). But, even though apraxia is common in AD and there is evidence that patients who develop apraxia may decline more rapidly than those who do not develop this symptom (Yesavage et al., 1993), there are few systematic studies on the nature of praxis dysfunction in AD. A growing literature on the subject describes an early impairment of semantic memory in AD, which is hypothesized to underlie deficits in the production of both language and meaningful gestures such as pantomimes (Bayles & Kasniak, 1987; Kempler, 1988). However, this unitary view is challenged by others (Ochipa et al., 1992; Rothi et al., 1991; Shallice, 1988), who claim that semantic memory can be subdivided into separate subsystems: the semantic knowledge of action necessary for executing pantomime and object use (action semantics); a verbal semantic system for naming; and a visual semantic system considered to be the repository of the visual properties of concepts. Thus, the relationship between action knowledge and verbal semantic deficits in AD is still a matter of debate. This study was designed to assess whether the action-semantic system can be dissociated from impairment of the verbal semantic system in AD patients through systematic analysis of profiles of limb apraxia.

Recent studies of apraxia have shown that AD patients display heterogeneous patterns of praxis deterioration and that limb apraxia occurs at different stages of the disease (Pena-Casanova & Bertran-Serra, 1993). Two types of limb apraxia have been consistently reported in AD: ideomotor apraxia (IMA; Foster et al., 1986; Rapcsak et al., 1989) and conceptual apraxia (CA; Benke, 1993; Lucchelli et al., 1993: Ochipa et al., 1992). IMA is defined as a difficulty in making gestures, attributable to an inability to translate the con-

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ceptual elements of a motor sequence into the correct motor action (Heilman et al., 1982). CA is defined as a failure to mentally evoke the gestures associated with an object, which results in difficulty in handling objects or carrying out complex goal-directed activities (e.g., cooking). The term "conceptual apraxia" was created to describe only apraxia resulting from an impaired knowledge of action (Ochipa et al., 1992) rather than the sequencing deficit defining ideational apraxia (IA; Poeck, 1983). We will use the term CA instead of IA because it acknowledges the fact that apraxics may also make errors using a single object (De Renzi & Lucchelli, 1988; Ochipa et al., 1989). Patients showing CA without concurrent IMA have been reported in the early to moderate stages of AD, suggesting that some apraxic AD patients have more of a conceptual than an ideomotor defect (Lucchelli et al., 1993; Pena-Casanova & Bertran-Serra, 1993).

Cognitive models of praxis postulate two major components: the conceptual and production subsystems (Rothi et al., 1991; Roy & Square, 1985). The conceptual subsystem involves three kinds of knowledge (action semantics): knowledge of the function that tools and objects may serve, knowledge of actions independent of tools, and knowledge about the organization of single actions into sequences. The model proposes that pantomiming the use of objects requires access to a conceptual system where the functions and uses of an object are represented (Roy & Square, 1985). The production subsystem includes information contained in action motor programs and its translation into skilled motor performance. Studies of left-brain-damaged and AD patients have shown that the two subsystems involve distinct mechanisms and can be subject to separate damage in apraxics (Heilman et al., 1997; Rapcsak et al., 1995). A disruption of the production system, or ideomotor apraxia, is characterized predominantly by spatiotemporal errors (postural and spatial orientation and spatial movement) during the imitation of gestures (Heilman & Rothi, 1994). In contrast, a disruption of the conceptual system, or conceptual apraxia, creates primarily content errors (perplexity, misuse, unrecognizable movement) and is manifested by the incorrect selection and conceptually inappropriate use of objects or tools (Ochipa et al., 1992). It is hypothesized that the basic deficit underlying CA resides in a loss or degradation of semantic knowledge defining the way an object is used. A conceptual deficit was proposed for all of the 32 AD patients studied by Ochipa et al. (1992) on a battery assessing tool and action knowledge. AD patients differed from normal controls on at least one measure of conceptual apraxia. The authors found that conceptual apraxia was not related to language impairment or to ideomotor apraxia, suggesting a selective deficit of "action semantics."

However, the notion of multiple semantic systems and the possibility of a separate action-semantic system are controversial (for a complete review, see *Neurocase*, Vol. 4, 1998). Neuropsychological evidence for multiple semantic subsystems comes from a number of different sources: optic aphasia, category-specific semantic loss, and dissociation of praxis and language in AD patients (Riddoch et al., 1988). Ochipa et al. (1992) and Raymer (1992) both support this notion of an action-semantic system that is at some level dissociable from other forms of semantic knowledge using different experimental paradigms in AD patients. Recently, Buxbaum et al. (1997) described 2 patients with degenerative disease: one, D.M., had a loss of functional and associative knowledge, but remained able to use objects and perform more complex tests of action; the other, H.B., exhibited the reverse pattern, namely, an inability to perform action tasks but no impairment in semantic memory. The authors concluded that intact semantic memory for objects is neither necessary nor sufficient to ensure good object use when acting in the environment. Their findings supported the hypothesis that a sensorimotor pathway exists (from the visual structural descriptions of objects to the output action system) that bypasses the semantic system, as proposed by Riddoch et al. (1989). A recent case study of an AD patient (E.J.), who showed impairment in object use, also investigated the relations between object use and semantic memory (Moreaud et al., 1998). The findings revealed no difference between E.J.'s semantic knowledge of objects correctly manipulated and objects incorrectly manipulated. These results suggested that semantic knowledge (including verbally expressed knowledge of object use) and object use are independent. However, no comparisons were made between E.J.'s poor performance in pantomiming the use of objects (to verbal and visual command) and his performance in the semantic knowledge tasks (naming, knowledge of use). Altogether, these data suggest that verbal semantic knowledge of objects is relatively independent from the action knowledge necessary for using them.

By contrast, other studies support the position of a unitary and amodal semantic system containing all semantic information about objects (Caramazza et al., 1990). Significant relationships between verbal semantic and pantomime impairment have been described in patients with AD (Taylor, 1994; Wang & Goodglass, 1992). For instance, Kempler (1988), in his study of apraxia in 8 AD patients, reported significant correlational and qualitative parallels between impairment in pantomimes of use and in verbal production and comprehension. The author suggested that lexical semantic representation may be intrinsically tied to representation of pantomimes since participants showed impaired access in both types of representations. Rapcsak et al. (1989) studied apraxia in 28 patients with AD and found that conceptual apraxia in AD was always associated with poor verbal comprehension. A significant relationship between pantomimes of use and verbal semantics (naming and verbal comprehension) was also found in a group of 20 AD patients, along with gestural communication impairments (Glosser et al., 1998, p. 13). The authors concluded that there was "a disruption of a common semantic system that might underlie the apparent associations of limb apraxia, communicative gestures, and language dysfunction in patients with AD." Finally, a recent study of conceptual apraxia by Heilman et al. (1997) in a group of 11 left-hemisphere-damaged apraxics revealed a significant correlation between verbal comprehension scores on the Western Aphasia Battery and each subtest of the conceptual apraxia battery, which was also used in the study by Ochipa et al. (1992) mentioned above. Thus, the absence of a significant correlation between verbal semantic impairment and conceptual apraxia in Ochipa et al.'s (1992) study may be confounded by the use of a brief verbal comprehension task, which was the only measure of verbal semantic integrity.

The results of previous studies of CA were limited by (1) few and overly broad tests of apraxia (often limited to only one test to diagnose limb apraxia, no testing of real use of objects); (2) insufficient number of stimuli to assess apraxia; (3) only one verbal measure of semantic knowledge (e.g., picture naming or verbal comprehension). We wanted to examine the relationship between measures of action-semantic knowledge and other measures of semantic knowledge while taking these possible confounding factors into account. If action semantics is part of the central semantic system, one would predict that AD patients who have conceptual apraxia will also display impairment on verbal semantic tasks. On the other hand, if action semantics is dissociable from other types of semantic knowledge about objects, then some patients should have a conceptual apraxia without impairment of semantic knowledge. In order to test these hypotheses, we assessed conceptual praxis using a comprehensive apraxia battery and we examined various aspects of semantic knowledge using verbal and visual tasks with 10 AD patients. We also examined the patterns of apraxic disturbances for each patient.

METHODS

Research Participants

AD patients

Ten patients fulfilling the NINCDS–ADRDA criteria for clinical diagnosis of probable Alzheimer's disease (McKhann et al., 1984) participated in this study. All patients were right-handed. The mean age for the AD patient group was 77.8 (range 71–83) and the mean education level was 9.1 years (range 5–15). There were 9 women and 1 man. They met the following criteria: modified Mini-Mental Examination scores (3MS; Teng & Chui, 1987) higher than 50 (range 51–72), adequate vision and hearing, cooperative, and consenting. The patients were screened with a neuropsychological battery to exclude any with visual agnosia. The patients' history was free of substance abuse, alcoholism, psychiatric episodes, head injury, or other known neurological diseases.

Controls

The control group consisted of 27 neurologically and neuropsychologically intact, right-handed participants. The mean age for the control group was 74.8 years (range 67–83) and the mean education level was 11.1 years (range 5–17). Student's t tests revealed nonsignificant differences for age $[t(35) = 0.1, p > .05]$ and schooling $[t(35) = .06, p > .05]$ between the two groups.

All participants were administered a thorough neuropsychological examination (see Joanette et al., 1995), for a description). In the AD group, the results revealed mostly mild to moderate deficits on tests of memory, language, visual perception and constructive abilities, and conceptualization. A significant correlation between performance on the neuropsychological battery and performance on the experimental tasks was found ($r_s = .867$; $p < .01$), suggesting that the experimental tasks appropriately reflected the patient's global level of cognitive functioning. Neuropsychological test results are not listed in detail because they are not directly relevant to this investigation.

Statistical analyses were conducted on both groups for the variables of interest and also between the performance of each AD participant and the norm for each task established by the control group ($M - 2SD$) to investigate for cases of dissociation.

Materials and Procedure

Assessment of semantic knowledge

We used three tasks to test semantic memory: verbal comprehension (COM), naming (NAM), and a visual semantic matching task (VSM). The COM task assessed patients' ability to match a word or a short sentence with a corresponding picture that appears along with three distractors (semantically related, perceptually related, and phonologically related to the target; maximum score = 47). For instance, the patient hears the word "dog" and must point out the correct picture among the distractors. The NAM task consisted of asking the participant to name an object or category of objects represented in a picture (maximum score = 31). The VSM task is meant to evaluate the ability to attribute a semantic value to a visually perceived object; this test is designed to examine the integrity of visual semantics. The patient was asked to match a picture with either a functionally related or a category-related picture target presented among perceptual and semantic foils (maximum score = 20).

Assessment of praxis (conceptual system and production system)

Five experimental tasks were chosen to assess both components proposed in the cognitive model of praxis (Rothi et al., 1991): the conceptual praxis system (gesture recognition task, assessment of conceptual apraxia, sequential task) and the production praxis system (CHCN apraxia battery, Multiple Object Test). Most of the tests employed have been described in detail elsewhere (De Renzi & Lucchelli, 1988; Lehmkuhl & Poeck, 1981; Ochipa et al., 1992; Ska et al., 1994) and were selected to facilitate comparisons across studies. Errors were computed for each task, since both content

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and production errors can lead to an impaired performance in executing pantomimes or object use.

Assessment of the conceptual praxis system

First, the ability to comprehend pantomimes was assessed by means of a subtest from the *Gesture Recognition Task* (Rock & Ska, 1994). This test comprises 22 gestures (two examples, 10 pantomimes of use and 10 symbolic gestures) that are performed slowly by the examiner. A gesture may be repeated three times if necessary. The participant is asked to identify the presented gestures by naming or by showing understanding of them (e.g., circumlocutions were accepted). Each item is scored on a binary system (1 for a correct answer) and thus the maximum score for this task is 20.

Subtests from the *Assessment of Conceptual Apraxia* (Ochipa et al., 1992) were used to assess patients' action semantics associated with tools or objects. To assess for content errors, 12 common tools and their corresponding objects were selected (2 demonstration and 10 test items) according to the protocol in Ochipa et al. (1992). Before administering the test, all participants were asked to point to tools named by the examiner to exclude visual agnosia and to ensure that they were familiar with the tools used. A tool was defined as an implement for performing or facilitating mechanical operations, such as a hammer. An object was defined as a thing to which a mechanical action is directed, such as a nail. The experiment was divided into three parts:

A. Demonstration of tool use holding the actual tool ("Take this tool in your hand and show me how you would use it").
B. Demonstration of tool use with only the object of the action present; patients were presented with a partially completed task (e.g., a nail that had been partially driven into a board) adjacent to a corresponding completed version (e.g., a nail completely driven into a board) that served to identify the goal of the task ("Show me—without the tool—how you would finish this task, as if you were really handling a tool").
C. Demonstration of tool use with both the tool and the object present ("Show me how to use this tool to finish this task").

A response was considered to have the correct content if the participant made a motion demonstrating knowledge of the type of action applied to the corresponding tool. The following responses were considered as content errors: tools not used (perplexity), unrecognizable movements (no content), movements incorrect for the tool in question but correct for another tool (substitution errors: related or unrelated content error) and omissions (incomplete gestures). We considered body part as object responses to constitute a partial ideational deficit because they may indicate different impairments of the propositional use of objects (Denny-Brown, 1958) or of differentiation between self and objects (Haaland & Flaherty, 1984). Production errors (content of movements is recognizable, but poorly performed, for example, the movement is poorly executed) were also considered to be incorrect performances and were recorded for additional analyses without being included in the scoring of the subtest.

We also assessed the action-semantic system with a *sequential task* devised by Lehmkuhl & Poeck (1981). This test evaluates the sequential organization of everyday actions and does not include the actual use of objects. The stimulus material consists of eight sets of five to seven photographs: each photograph portrays a well-defined stage of an everyday action. These actions were brushing teeth, opening a bottle of wine, preparing a cup of coffee, opening a tin and pouring the contents into a pot, telephoning, hanging a picture on the wall, and punching paper and putting it in a loose-leaf binder. The structure of the test material is illustrated in the original paper (Lehmkuhl & Poeck, 1981). In each set of photographs, the first picture of the sequence shows the objects needed to carry out the action. With the aid of this picture, the patient is made familiar with the action depicted in the sequence. He is then presented with the randomized arrangement of pictures and is requested to put these in the correct sequence. The patient is free either to arrange the pictures himself or to indicate to the examiner which one should come next. Performance was scored according to the number of sequential errors in each item.

Assessment of the production praxis system

The production system was assessed with three tests taken from the *CHCN Apraxia Battery* (Ska et al., 1994), which included the testing of pantomimes of use (e.g., to use scissors; $n = 12$), symbolic gestures (e.g., to execute a military salute; $n = 9$), and meaningless gestures (e.g., to touch the thumb with the index finger: corresponded either to a single gesture or to a sequence of manual gestures; $n = 13$) performed with the dominant hand.

Pantomimes were executed in response to verbal commands, in imitation of models presented by the examiner, and in response to photos of objects. Two aspects of the execution of pantomimes were rated separately: (1) the shape of the hand and (2) the movement and respect of the spatiotemporal component of the gesture. For instance, for a verbal request such as "Show me how you brush your teeth," Score 1 corresponded to the shape of the hand holding the toothbrush, and Score 2 to the movement and position of the hand with respect to the mouth while brushing the teeth. Scoring of each aspect was binary (0 or 1) and thus the maximum score was 24. Prior to testing, the examiner explicitly instructed all the participants that, as they executed the pantomimes, they should pretend they had the actual tools or objects in their hand. Participants were reinstructed only for the two first examples when they made a body part as object (BPO) response and not for subsequent BPO responses. Symbolic gestures were executed on verbal command and in imitation, with the same scoring procedure as described above for pantomime (maximum score = 18). Meaningless gestures were performed in imitation only and the scoring took into account four parameters: (1) hand shape (for each hand), (2) spatial orientation of the hand, (3) position of the body part, (4) respecting the laterality (e.g., executing the gesture with the same hand as the one used by the examiner; maximum score of 52). The tasks were presented in an order designed to avoid a practice effect (first session: verbal command, imitation of meaningless gestures; last session: pantomime to photos of objects, imitation of pantomimes, and symbolic gestures). Items included unimanual and bimanual gestures that were executed in intrapersonal or extrapersonal space. The testing sessions were videotaped for detailed analysis of the performances. Videotaped gestures were rated separately by two judges who reviewed them until they were in full agreement.

Finally, we also administered the *Multiple Objects Test* (MOT; De Renzi & Lucchelli, 1988) to assess the production of praxis in a more contextualized setting. Participants were instructed to use real objects in five action sequences, as summarized in Table 1. The objects for the MOT were arranged separately for each action on a table in front of the subject; next, the goal of the action was stated explicitly, without mentioning the steps of the action. Errors were counted and classified in the following categories (for a more detailed description, see De Renzi & Lucchelli, 1988): first, we computed production errors such as *clumsiness* (awkward but conceptually appropriate motor performance) and *mislocation* (objects put in wrong locations—spatiotemporal error using the object). We then considered content errors such as *perplexity* (disorientation, trial-and-error behavior), *omission* (deletion of an action), *misuse* (conceptually inappropriate object use), and *sequence errors* (wrong order of actions). Each error type was counted only once per action in order to avoid measuring perseverative errors (maximum number of possible errors = 6).

RESULTS

Assessment of Semantic Knowledge

The results of the three tasks evaluating different aspects of verbal and visual semantic knowledge are presented in Table 2 along with patient information. All patients were below the cut-off on at least one semantic task: 90% were impaired in comprehension (M = 45.9, SD = 1.1; cut-off = 44), 80% in picture naming (M = 30.4, SD = 0.4; cut-off = 29), and 60% in the semantic visual matching task (M = 19.9, SD = 0.3; cut-off = 18). In 5 cases (50%), patients were impaired on all semantic tasks.

Table 1. Actions in the Multiple Object Test

Title	Instruction
Candle	Place candle on candlestick, strike match and light it
Drink	Open bottle, poor mineral water into glass, drink
Padlock	Insert key in padlock, open, lock the chain in, then close padlock
Letter	Fold page, put it in envelope, seal envelope, stick stamp in correct position
Tea	Open tea caddy, put tea bag in teacup, pour water from kettle

Table 2. Results of semantic tasks for AD participants

Participant	Age	3MS**	COM (/47)	NAM (/31)	VSM (/20)
1	71	72	43*	31	20
2	74	60	43*	25*	17*
3	79	51	22*	27*	18*
4	82	50	36*	16*	16*
5	76	64	40*	21*	19
6	78	57	41*	28*	18*
7	83	66	38*	28*	19
8	82	68	44	26*	20
9	80	63	43*	27*	18*
10	73	63	22*	30	17*

*significantly impaired ($M - 2SD$).
**The modified Mini-Mental State score.
Note. COM (comprehension); NAM (picture naming); VSM (visual semantic matching task).

Assessment of the Conceptual Praxis System

The results of the conceptual tasks for AD participants are shown in Table 3.

Compared to the control group, 6 AD patients performed below the cut-off on the *Gesture Recognition Task* (M = 19.52, SD = 0.7; cut-off = 18). In AD patients, recognition of pantomimes produced slightly more errors than the recognition of symbolic gestures (19 errors *vs.* 13 errors), which suggests that pantomimes of use may be more complex to recognize. However, the distribution of errors was not significantly different from the control group ($\chi^2 = 0.018$, n.s.). The 6 AD patients who performed poorly in recognition of gestures also performed poorly in executing pantomimes of use, whereas the reverse pattern was not observed since some patients had impaired pantomiming without any recognition deficit ($r_s = 0.19$, $p > 0.05$). Gesture recognition scores correlated significantly with the modified Mini-Mental scores ($r_s = 0.75$, $p < 0.01$) for AD participants.

On the *Conceptual Apraxia Battery*, 7 AD patients performed below the cut-off set by the control group (M = 28.3, SD = 2.1; cut-off = 24), showing conceptual apraxia (see Table 3). Profiles were heterogeneous since deficits were observed for one subtest (S6, 7, and 9), two subtests (S2 and 8) or all subtests of the battery (S3 and 4). Table 3 shows that Task C (handling the tool in presence of the object receiving its action) was performed almost flawlessly by 6 AD patients, whereas 2 patients were below the cut-off; however, these results underestimate patients' performance and were attributable to the ceiling effect observed in normal

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Table 3. Results of conceptual tasks for AD patients

Participants	3MS**	Rec. (/20)	Seq. (/8)	C. bat A (/10)	C. bat B (/10)	C. bat C (/10)	C. bat total (/30)
1	72	20	7	9	6	10	25
2	60	17*	2*	8*	4*	9	21*
3	51	16*	3*	8*	1*	8*	17*
4	50	9*	—	8*	2*	8*	18*
5	64	15*	7	9	9	10	28
6	57	15*	1*	9	3*	10	22*
7	66	19	5	10	3*	10	23*
8	68	20	0*	8*	4*	10	22*
9	63	20	5	10	1*	9	20*
10	63	17*	4	10	6	10	26

*significantly impaired ($M - 2SD$).
**The modified Mini-Mental State score.
Note. Rec. = gesture recognition task; Seq. = sequential task; C. bat = conceptual apraxia battery (Conditions A, B, C, and total).

controls since they performed Task C without error. Nonetheless, the 2 patients who scored below the controls in Task C were impaired in all tasks of the battery, suggesting that they definitely had a deficit in handling tools regardless of a possible underestimation of their performance in Task C. Figure 1 also demonstrates that Task B (showing tool use with only the object present) was particularly difficult for AD patients: 7 patients scored below the cut-off of 5. This task was also more difficult for controls, as the high frequency of errors reveals: AD patients made 79% of all their errors in Task B, whereas the amount for controls was 91%. Patients were often perplexed and did not know what to do with the object (e.g., a nail that had been partially driven into a board), even after the example was shown. For instance, some patients tried to pull the nail out instead of hammering it in, as was represented by the completed object (a nail completely driven into a board). These items seemed to be very ambiguous even when the completed object was presented along with the incomplete object to define the goal of the task. The most frequent type of error for both groups was BPO (AD = 57%; controls = 66%), followed by omission or incomplete action (AD = 30%; controls = 21%) in Task B. Production errors (movement is poorly executed) were few for AD patients and controls and did not seem to underlie failures on these tasks. There was no significant difference between the distribution of types of errors for AD patients and controls. Three patients performed as well as controls on the conceptual apraxia battery (S1, 5, and 10).

The *Sequential Task* was administered to 9 AD participants (1 patient became confused and refused to complete it). Four patients scored below the cut-off set by the control

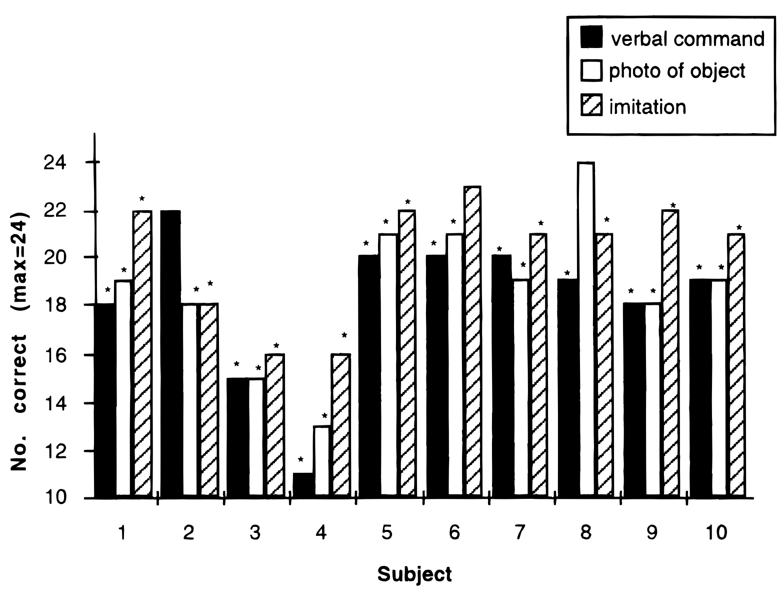

Fig. 1. Results of the pantomime of use task for AD patients.

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group ($M = 6.6$, $SD = 1.2$; cut-off = 4) and were found to be impaired on this task (see Table 2). Taken as a group, AD patients made 3 times more sequential errors than controls (in proportion, 5.3 *vs.* 1.7 for controls) when putting the pictures depicting an everyday action into the correct sequence. The highest frequency of sequential errors was found for the item, "Open up a bottle of wine," for both groups (it accounted for 25% of all sequential errors for AD and 25% for controls). For instance, many patients failed to notice that there was wine in the glass and placed that picture before one showing someone opening up the bottle of wine. Multiple comparisons of the frequency of errors on the items for AD patients and controls were not significant and revealed no significant difference between the two groups.

To determine the relationship between action–tool knowledge and other measures used to assess action semantics, we computed Spearman correlation coefficients between the conceptual apraxia battery scores and recognition scores, and between conceptual apraxia battery scores and sequential test scores for the AD patient group (see Table 4). None of these comparisons were significant.

Assessment of the Production Praxis System

Table 4 shows the comparison of AD patients' performance with normal controls in executing different types of gestures in the three conditions.

The AD group differed significantly from normal controls on all measures, except in imitating meaningless gestures. A qualitative analysis showed that AD patients made significantly more errors in executing pantomimes of use (proportion of error for the three conditions) than in imitating meaningless gestures [$\chi^2(1) = 34.593$, $p < .01$]. The execution of symbolic gestures on imitation was practically flawless for both AD patients (4 errors) and controls (1 error), whereas 4 patients were below the cutoff score in executing symbolic gestures to verbal command ($M = 17.4$, $SD = 1.2$; cut-off = 15). Meaningless gestures were significantly impaired in only 2 patients: the errors were mostly lateralization errors (transposing perceived left and right coordinates on their own body; 42% of errors for AD patients and 61% for controls). There were significantly more errors of lateralization than errors of spatial orientation in the execution of meaningless gestures by AD patients [$\chi^2(1) = 4.86$, $p < .05$].

The results of the pantomime of use task for each AD patient are depicted in Figure 1. In executing pantomimes of use, 9 patients performed below the controls in pantomiming to verbal command ($M = 23.1$, $SD = 1.2$; cut-off = 21), 9 patients were impaired in pantomiming to photos of objects ($M = 23.5$, $SD = 0.9$; cut-off = 21), and 9 in imitating pantomimes of use ($M = 23.7$, $SD = 0.5$; cut-off = 22). Overall, patients made significantly more errors in executing gestures to verbal command than did controls [$\chi^2(1) = 4.076$, $p < .05$]. An analysis of the performance of each patient in executing pantomimes of use revealed that 7 patients showed impairment in all conditions of presentation, whereas there were 3 cases of dissociation: 1 patient (S2) showed preserved ability only on verbal command but was impaired on the imitation and visual input tasks; 1 patient performed correctly on imitation but was impaired on the verbal and visual stimulus tasks (S6); and another (S8) performed normally in response to photos of objects but was otherwise impaired in the verbal command and imitation conditions.

The distribution of errors in performing pantomimes of use was similar for patients and controls since AD patients made 70% BPO errors and 30% movement errors, whereas controls made 62% BPO errors and 38% movement errors. Both groups made mostly BPO errors across all conditions (AD = 43% of all errors; controls = 39%), but AD patients made statistically more BPO errors [$\chi^2(1) = 6.222$, $p < .05$] and more spatial errors [$\chi^2(1) = 11.196$, $p < .01$] than controls. A dissociation between IMA and CA was found in 2 cases (S1 and S10), who were impaired in pantomiming to verbal command (with production errors) and in im-

Table 4. Comparison of the AD group with normal controls on the three subtests of the CHCN apraxia battery

	AD ($N = 10$)		Controls ($N = 27$)		
Task	*M*	*SD*	*M*	*SD*	*t*
Verbal command					
Pantomimes of use	18.2	3.1	23.1	1.2	6.73**
Symbolic gestures	14.7	1.2	17.4	1.2	5.77**
Imitation					
Pantomimes of use	20.2	2.5	23.7	0.5	6.48**
Symbolic gestures	17.6	0.7	17.9	0.2	2.40*
Meaningless gestures	46.5	3.7	49.4	3.6	2.0
Photos of objects					
Pantomimes of use	18.7	3.0	23.5	0.9	7.08**

*statistically significant at $p < .05$.
**statistically significant at $p < .01$.
Note. P values are two-tailed.

itating pantomimes but had preserved conceptual knowledge of actions.

Finally, only 3 AD patients failed the highly contextualized Multiple Objects Test (S3, S4, and S6). The same 3 patients were impaired on all measures of conceptual apraxia (recognizing pantomimes, the conceptual apraxia battery, the sequential task) and on measures of pantomime production (verbal and imitation), revealing an association of CA and IMA. Moreover, their performance on all tasks testing semantic knowledge of objects (comprehension, naming and visual semantic matching) was in the impaired range. In this test, the item, "Make tea," generated the most errors in AD patients (57% of all errors), whereas the item "Padlock" was associated with the highest frequency of errors for controls (50%). The most frequent errors for AD patients were omission (71%, for instance, many patients forgot to glue the stamp; 50% for controls), followed by sequence errors (20%). Multiple correlations between the frequency of errors for AD patients and controls were not significant at the .05 level.

Relationship Between Action Semantics and Verbal–Visual Semantics

To determine the relationship between action semantics and semantic memory, we computed multiple Spearman correlation coefficients between action-semantic tasks (recognition, sequential, and action-conceptual tasks) and tasks of semantic knowledge (naming, verbal comprehension, and visual semantic matching tasks) for the AD patient group (see Table 5).

Gesture recognition scores were significantly correlated with scores on the visual semantic matching task ($r_s = .77$, $p < .05$) and on the verbal comprehension task ($r_s = .61$, $p < .05$) for AD patients.

A detailed case-by-case analysis revealed three different patterns of impairment between action semantics and verbal semantics: in 3 cases (S2, 3, and 6), AD patients were impaired in all semantic knowledge tasks (e.g., action and verbal). Six cases were impaired in one or two action-semantic tasks and in at least one measure of verbal–visual semantic knowledge (S4, 5, 7, 8, 9, and 10). Finally, only 1 patient (S1) had a preserved ability in action-semantic tasks despite a mild verbal comprehension deficit and signs of conceptual problems (e.g., content errors) in pantomiming the use of objects to verbal and visual command (but not in imitation). The 3 patients who were impaired in both action semantics and verbal–visual semantics also performed poorly at the pantomime of use and multiple-object-use tasks. Overall, this analysis suggests that 9 out of the 10 patients had impairments in both domains of semantic knowledge.

Table 5. Spearman correlation coefficients between six tasks assessing action semantic and verbal semantic performance for 10 AD patients

Task	T2	T3	T4	T5	T6 (VSM)
T1 (concept.)	.14	.50	.06	.37	.44
T2 (recognition)		.10	.61*	.48	.58*
T3 (sequential)			.22	.20	.26
T4 (COM)				.06	.51
T5 (NAM)					.32

*statistically significant at $p < .05$.

DISCUSSION

This study was designed to examine the patterns of apraxic disturbances and the relationships between measures of action-semantic and other semantic knowledge about objects (comprehension, naming, and functional–categorical knowledge) in AD patients.

Considering profiles of apraxia first, we found that 9 of the 10 AD patients showed evidence of conceptual apraxia in tasks assessing conceptual action knowledge. This result was not attributable to a selection bias since the patients were not selected on the basis of praxic impairment. Our findings concur with previous studies showing that conceptual apraxia is a common feature in AD patients, even in the early stages of AD (Benke, 1993; Lucchelli et al., 1993). Indeed, patients were impaired in recognizing pantomimes of use (60%), in sequencing actions (44%), and in the knowledge of tool–object action relationships (70%). Only 1 patient (S1) showed preserved conceptual knowledge of praxis on the five experimental tasks; however, he was impaired in pantomiming the use of objects to command (verbal commands and photos of objects), showing confusion and BPO errors, which suggests a subtle conceptual defect in the absence of a production deficit (no spatiotemporal errors, unimpaired in imitation of gestures). Our findings also support the proposed distinction between conceptual and production defects (Rapcsak et al., 1995; Rothi et al., 1991) since there were cases of dissociation between IMA and CA.

Like previous studies (Lucchelli et al., 1993; Pena-Casanova & Bertran-Serra, 1993), our results point to a greater conceptual than production defect in apraxic AD patients, since all participants were significantly impaired in performing pantomimes of use (with primarily content errors) to verbal or visual command, whereas their performance in imitating symbolic gestures was almost flawless. Imitation of gestures is held to be the most direct test of the integrity of the production system because the examiner provides a representation of the gesture that would otherwise have to be retrieved from the conceptual system. Meaningless gestures were significantly impaired in only 2 patients: the errors mainly involved lateralization. These lateralization or "mirror effect" errors were not considered as a pathological sign in previous work by Ska (1994), who found a high percentage of lateralization errors in a group of normal elderly people who were required to make meaningless gestures.

The qualitative analysis of errors also points to a dysfunction in the conceptual system since patients made primarily content errors in most experimental tasks (e.g., body part as object, substitution, omission, confusion) and very few movement errors (spatiotemporal errors, incomplete movement). Raymer et al. (1997) explained BPO errors as an impairment in implementing transitive postural representations, which are either destroyed or inaccessible. Six AD patients were simultaneously impaired in recognizing and in executing pantomimes of use to the photos of objects; this finding seems to confirm that their representations of action were somehow impaired (Heilman et al., 1982). Pantomime of use has consistently been shown to be preferentially impaired in AD (Rapcsak et al., 1989; Taylor, 1994). This finding might reflect the complexity of the pantomime of use task, which is a highly artificial act that does not take place in natural contexts. However, 4 patients out of 10 could not show the appropriate use of a common tool (that they had previously correctly identified) even when handling the actual tool, that is, in a concrete situation. Two patients improved significantly when they were given both the tool and the object of the tool's action (e.g., a hammer and a piece of wood containing a partially driven nail); they were also better at familiar everyday tasks (e.g., making tea in the multiple object test). Thus, the degraded representations of actions associated with tools may be sufficiently activated when there are numerous contextual cues to improve performance in tasks of object use, as other studies had found (De Renzi, 1985). It has been proposed that even patients with impaired action knowledge can perform object-use tasks and complex naturalistic actions using a direct, nonsemantic route from the visual structural descriptions of objects to the action output system (Buxbaum et al., 1997; Riddoch et al., 1988). The facilitating effect of visual contextual cues may be explained by the use of visual structural descriptions of objects to activate the action output system in case of a breakdown of the conceptual system. Thus, in addition to the action-semantic system, this nonsemantic route may also be impaired in the more severe cases of apraxia (patients S3, 4, and 6), since these patients could not benefit from visual contextual cues in using objects and tools.

Finally, we found cases of dissociation for each input modality in the pantomime production task (i.e., verbal command, imitation and to photos of objects). Such dissociations have previously been reported in a study of left-hemisphere-damaged patients (De Renzi et al., 1982). Modality-specific impairments in pantomiming are attributed to a selective deficit of a specific input system, that is, a disorder of presemantic processing for each modality, according to the cognitive model of praxis (Rothi et al., 1991).

Our second goal was to examine whether action semantics could be separated from the central semantic system in AD patients. We found partly parallel deficits in action-semantic and verbal–visual semantic tasks in 9 out of 10 AD patients. On the one hand, 3 AD patients were impaired in all tasks of semantic knowledge (i.e., action and verbal), thus demonstrating both impaired conceptual knowledge of actions (e.g., identifying pantomimes of use, knowledge of actions independent of tools, and knowledge of the organization of single actions into sequences), and impaired semantic knowledge of objects (e.g., naming, comprehension and the functional and categorical aspects of objects). The performance of these 3 patients (S3, 4, and 6) was also impaired in measures of pantomime production (verbal and imitation) and in automatized daily tasks such as the MOT, revealing an association of conceptual apraxia and ideomotor apraxia. Not surprisingly, their modified Mini-Mental Examination scores (3MS) were lower than those of other patients (respectively, 51, 50, and 57), suggesting that the severity of cognitive impairment is closely associated with the severity of apraxia, as was previously reported by Della Salla et al. (1987). On the other hand, 6 AD patients performed in the impaired range on one or two action-semantic tasks and at least one measure of verbal–visual semantic knowledge: the patterns of deficits were much more heterogeneous for patients in the early stages of the disease, as assessed by the 3MS. These data reflect the underlying heterogeneity that occurs in AD, since patients differ with respect to the occurrence of compromised semantic impairment and the anatomic distribution of their functional cerebral defects (Hodges & Patterson, 1995). Last, only 1 patient (S1) showed preserved action semantics (in tasks of action knowledge) with a mild verbal comprehension deficit and signs of a conceptual defect in pantomiming use of objects (e.g., content errors). This patient also had the highest scores on the neuropsychological assessment and on the 3MS examination, with a score of 72. It seems that the disorder may not yet have severely impacted the central semantic system in this early-stage AD patient.

Overall, none of the AD patients presented a selective impairment of action semantics without any other semantic deficit, which does not lend support to the notion that action semantics is separable from other components of semantics. In contrast, impaired action semantics was found in participants with a semantic language deficit, suggesting a global disturbance of the central semantic system in these patients. Moreover, a qualitative parallel emerged between the severity of conceptual apraxia and the severity of semantic language deficit. Previous investigators (Heilman et al., 1997) have also reported a relationship between conceptual apraxia and language impairment, using the conceptual apraxia battery, as in the present study. Furthermore, and despite the small number of patients, significant correlations were found between action-semantic tasks (gesture recognition score) and verbal–visual semantic tasks (comprehension score and visual semantic matching score) in the AD patient group. Our findings contrast with those of Ochipa et al. (1992), who found selective conceptual defects of praxis in AD patients without verbal semantic impairment, as tested by a single-word auditory comprehension task. We suggest that differences in the assessment of semantic impairment might explain this discrepancy, since we used three measures of semantic knowledge (two verbal and one nonverbal) compared to only one verbal measure in the study of Ochipa et al. (1992). Given that impairment of a neuropsychological function is indicated by the convergence of results on tasks believed to assess that function (Lezak, 1983), one

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test of verbal semantic knowledge may not provide conclusive evidence of the integrity of that function.

Impairments in both verbal and action domains might be a fortuitous finding resulting from the neuroanatomical contiguity of these systems, which may be underlied by similar regions affected by the disease process. However, the findings do not seem to support this interpretation. First, analysis of individual AD profiles showed a parallel deficit of verbal semantic knowledge and action knowledge in 9 patients; furthermore, the severity of conceptual apraxia (action knowledge) was proportional to the severity of a deficit in verbal semantic knowledge in these patients, suggesting at least a parallel functional deficit in both domains. Second, it seems unlikely that these 9 AD patients all showed identical lesions of the same cerebral networks that underlie these functions, given the well-known heterogeneous profile of neurological and neuropsychological impairments in AD (Fisher et al., 1997). If action semantic and verbal semantic knowledge were different subsystems, the individual profiles would probably have been more heterogeneous (impaired verbal and spared action) and of various severity.

In contrast to those of other investigators (Ochipa et al., 1992; Shallice, 1988), our findings provide no strong evidence that action semantics may be separated from other semantic information. Rather, our results support the hypothesis of a unitary semantic system, where the representations of action and of other semantic knowledge of objects are often simultaneously disrupted in Alzheimer's disease (Kempler, 1988; Rapcsak et al., 1989). Buxbaum et al. (1997) suggested that the same semantic representations of objects are called upon in action and nonaction tasks, but in very different ways. They argued that difficulties in representing information about object function may be present in nonaction tasks while largely absent in action, since sensorimotor elements recruited directly from perception may enhance degraded functional–associative knowledge of objects. We agree with this position and find support for it in the fact that 6 AD patients' performance on actual object use (MOT) was preserved in spite of impaired semantic knowledge in tests believed to tap into action semantics and verbal–visual semantics.

Previous evidence revealed that AD patients' functional knowledge of objects might be particularly impaired in tasks assessing functional attributes (e.g., for a saw: "Is it used to cut things?"; Chertkow et al., 1989). Johnson and Hermann (1995) also found that both mild and moderate AD patients showed a disproportionate disruption of functional attributes of objects compared to other attributes (e.g., category, part, property). This impairment in the functional knowledge of objects could become apparent in actions associated with objects. Therefore, conceptual apraxia in AD might be the consequence of an early semantic memory deficit affecting the functional knowledge of objects and, in some cases, their use.

We suggest that these findings are best accounted for by a conception of semantic organization in which knowledge of an object is represented by a central, distributed network of features, including the way the object is used. Semantic knowledge is retrieved and expressed via different input and output processes that may be selectively impaired (Caramazza et al., 1990; Riddoch et al., 1988), thus accounting for the different patterns of impairment in AD patients and the weak significant correlation between action knowledge and verbal–visual knowledge. Unfortunately, we did not use the same stimuli in the tasks of praxis and of verbal–visual semantic ability and thus we cannot compare performance on the same item, which might have indicated whether representations underlying names and gestures were destroyed or only partially inaccessible across different stimulus input modalities. Nonetheless, it seems reasonable to suppose that disruption of a common semantic–conceptual system may underlie the apparent association of conceptual apraxia and semantic knowledge deficit in patients with AD, though a larger sample will be needed to test these relationships in more detail in future studies.

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