

## **Loss of High-level Perceptual knowledge of Object Structure in DAT**

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## **Abstract**

Visual object recognition and naming deficits in patients with dementia of the Alzheimer type (DAT) have typically been attributed to deficits in semantic processing. On a visual object naming test, a group of mild DAT patients were found to suffer from anomia, compared to an age-matched control group. DAT naming errors were typically within category (commission), associative or circumlocutory errors. Performance on tests of low level visuo-spatial ability fell within the normal range. Together these results suggested that anomia resulted from a dysfunctional semantic system with intact visual perception. However, in a naming task using visually degraded images of familiar objects, the recognition threshold in DAT patients was significantly higher, indicating the need for a more visually complete object representation, before it could be accurately recognised. In a matched task using words visually degraded in an identical manner, the recognition threshold for DAT patients was very similar to that of the control group. It is argued that these results support the idea that impaired structural descriptions of objects (i.e., pre-semantic representation of an object within the visual perceptual system) combines with degraded semantic representations to produce anomia in DAT.

*Keywords:* Alzheimer's-Disease; Dementia-; Human-Information-Storage; Object-Recognition; Object-Naming; Visual-Perception.

## **Caption: Object Naming Impairments in Dementia**

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## 1. Introduction

Visual object naming difficulty is an early and consistent feature of DAT (Dementia of the Alzheimer Type), which typically worsens with disease progression [21]. Anomia observed in DAT patients on tasks requiring visual object recognition has for some time been attributed to degradation of semantic representations. Explanation in terms of visuoperceptual impairments tend to be ruled out as the same patients compare favourably with matched controls on visuo-perceptual tests [3,5,6,35]; or that naming errors are deemed to be semantic associates with few, if any, explicable on the basis of perceptual misidentification [1,12,29,21,22].

Despite considerable evidence that anomia in DAT arises from a loss of stored semantic representations, we suggest a number of reasons to re-examine whether perceptual knowledge about object structure or “structural descriptions” [2,28] are degraded in DAT and reappraise whether the methodology used to date can eliminate these deep levels of perceptual processing as contributing factors in anomia. Object recognition is the end stage of a series of visual information processing stages [10], with early stages (e.g. in V1-V2) involved in form perception such as feature detection and global form or contour recognition, which subsequently give way to intermediate stages which permit shape and size discrimination, orientation and elementary spatial localisation [10,16]. Bifurcation of the visual system into the ‘what’ and ‘where’ systems mean that late stages in the ‘what’ or ventral system involve access to the structural descriptions of objects, at which stage object recognition occurs. Late stages in the ‘where’ system are more responsible for localising objects in space [33] or providing egocentric frames of reference which guide goal-directed actions [16]. Neuropsychological tests of visual-spatial or form constancy, shape, size, figure –ground discrimination, visual closure or localisation, tell us about the intactness of early, intermediate or late stages of the ‘where’ system. The integrity of structural descriptions cannot be inferred from such tests.

Neuropsychological tests used to examine structural descriptions, especially in visual agnostic patients have included object decision tests (deciding whether a picture is a real or unreal object [41]), recognising sketchily drawn [32], incomplete [49] or fragmented forms of objects (such as Gollins Incomplete Figures [14]), matching usual and unusual views of objects [23], and drawing from memory [23]. Similarly, tests of structural descriptions with neurologically intact subjects have typically involved restricting the type or quantity of visual information [19,37], or degrading the image by removal of features [43]. Some agnostic patients fail these tests without impaired early/intermediate visual perception together with intact semantics. Such results are understood by inferring that impaired object perception results from a loss of structural descriptions for those objects.

The inferotemporal (IT) cortex is believed to be critically involved in processing of structural representations involved in visual object recognition [10,16,26,]. The typical pattern of pathology in DAT patients with anomia includes the IT cortex [38], and it is the pathology in this region which is assumed to be largely responsible for DAT anomia. One would therefore expect stored structural descriptions to be degraded in patients with IT pathology in addition to any degraded semantic memory. However, since neuropathology and functional activation can vary considerably between the ‘what’ and ‘where’ systems in different DAT patients [4,15,25,39,42],

impaired performance on visuo spatial perceptual tasks may not correlate with performance on tests assessing structural descriptions. Collectively, this evidence would indicate that one might expect to find degraded structural descriptions in anomic DAT in addition to (well-documented) loss of semantic representations.

Published evidence implicating degraded structural representations in DAT object processing is limited, however. Impaired performance in DAT patients on the Gollin Incomplete Figures has been reported [7], as has impaired object decision [11,18]. Further, reduced contrast sensitivity for low frequencies which would impair form perception has also been reported [7,42]. Interestingly this contrasts with the normal ageing process where it is the higher frequencies that are impaired first [42]. However, evidence suggesting intact structural knowledge in DAT patients has also been reported. Structural similarity does not result in name confusion or delayed name latency [47]. Intact perceptual priming with pictures has also been found in DAT, indicating that high level perceptual representations are intact when accessed implicitly [11,36]. Having said this, there has been no previous direct attempt to relate performance on these tests of structural descriptions to anomia in DAT.

DAT anomic error analysis has indicated deficits at the level of stored semantic knowledge rather than at the level of stored structural knowledge. Superordinate or coordinate errors using the error analysis scheme of Hodges et al. (1991) [21] are deemed to be semantic, rather than perceptual errors [35]. However such errors are also consistent with impairments at the level of the structural description system [30,40], since imprecision in accessing stored structural knowledge will cascade down to the semantic system to produce superordinate errors rather than visual errors [30].

The study reported here utilises a method widely used in research on structural descriptions in normal subjects [43], and involves examining the effect on picture recognition, of systematically removing featural, or higher frequency, visual information. DAT patients with mild anomia were asked to recognise these fragmented pictures, which they were otherwise able to recognise when complete. Since DAT patients are reported to show 'undersampling' [42] - i.e. that only a portion of all salient features of the image are processed, it was necessary to control for this by using degraded words as well as degraded pictures. It was hypothesised that if DAT anomia does in part result from degradation of stored structural knowledge of objects, then recognition of known objects will be substantially impaired when features are degraded. However, if words are substituted for pictures and the test is repeated, then DAT patients, with normal levels of word recognition, should be unimpaired since word recognition does not involve access to the structural description system used in naming visually presented objects [8,10].

## **2. Methods**

### ***2.1. Patients***

The 10 DAT patients were screened from an initial sample of 29, using the following criteria: (i) mild enough level of dementia to ensure they did not have comprehension problems in understanding the tasks; (ii) a score of less than 4 on the Hachinski Scale [17], reducing the risk of a non-DAT aetiology; (iii) no indication of presence of potentially confounding neurological disorders, severe metabolic disorders, head

injury, or prior psychiatric illness. A diagnosis of probable DAT was made according to the inclusion and exclusion criteria of National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) and the Alzheimer's Disease and Related Disorders Association (ADDA) [31]. Neurological laboratory tests and assessments, where available, failed to suggest other causes of dementia. Patients all presented with progressive cognitive deficits predominantly affecting memory with a disease history of between 2-5 years. All were aged over 61, with a mean age of 74.2 years (range 61-85, S.D. 8.2) and a mean education of 10.0 years (range 9-12, S.D. 1.4). Informed consent was obtained from all participants or their caregivers, prior to their inclusion in the study. The NART-FSIQ (Full-scale IQ) [34] yielded a mean of 109.9 (range 98-119, S.D. 9.4). Generalised cognitive status, as measured by MMSE (Mini-mental State Examination) [13] yielded a mean score of 23.8 (range 19-29, S.D. 2.9); indicative of a relatively mild degree of dementia. All were native English speakers, had no hearing difficulties, and had normal or corrected-to-normal vision.

## ***2.2. Control subjects***

This group consisted of 10 normal elderly people, the majority of whom lived in the same area, and attended their local social services community centres. None had any history of hypertension or alcoholism, and did not display any signs of cognitive decline. They were aged 68 and over, with a mean age of 73.4 years (range 68-83, S.D. 4.7), which was not significantly different from the DAT group ( $t = -0.27$ , [18],  $P = 0.79$ ). The mean education level for the group was 9.8 years (range 9-14, S.D. = 1.6), which, again, was not significantly different to that of the DAT group ( $t = 0.294$ , [18],  $P = 0.77$ ). The control subjects were matched to the DAT subjects according to professional status prior to retirement. The NART-FSIQ [34] yielded a mean of 108.4 (range 101-119, S.D. 5.9), which was not significantly different to that of the DAT group ( $t = 0.43$ , [18],  $P > 0.05$ ). The mean MMSE scores of the control group (range 25-30, S.D. 1.7) were significantly higher than that of the DAT group ( $t = 3.92$ , [18],  $P < 0.001$ ).

## ***2.3. Tests of Visual Perception***

To rule out deficits in elementary shape perception, the Efron shape matching test [9] was employed, in which subjects decided whether any given pairs of rectangular shapes were same or different. To rule out the possibility of gross apraxia a figure copying test was administered, in which subjects were asked to copy four simple geometric shapes (square, circle, triangle, diamond). Additionally, a number of subtests from the VOSP (Visual Object and Space Perception) Battery [50] were used, including Dot Counting, Position Discrimination, and Number Location, which are increasingly more difficult tests of spatial scanning and spatial perception. Further, the authors devised and used a modified version of Cube Analysis subtest, to assess a subject's ability in interpreting a 3D shape in terms of its two-dimensional constituent parts – a process thought to be involved in construction of the 3-D model [27,28]. The modification offers better internal validity as a test of 3-D model construction, since it reduces the demands on working memory. Correct performance on this test not only requires an intact ability to translate between 3D and 2D representations of the constituent blocks making up the shapes, but also the ability to perform mental rotations of the shapes themselves [18].

Subjects also carried out the Authors' own version of the unusual Views task [51,52] in which the stimuli were constructed using the same principles as the original test [18]. This assessed object constancy and the integrity of structural representations. Subjects were presented with a picture triad, and asked to select which two pictures showed the same entity from different views.

### **2.3.1. Results**

As a group, the DAT subjects were not significantly different to the control group in their scores on tests of visual perception. A comparison of DAT and Control groups' performance on each test of visual perception is shown in Table 1, in which the data generally points towards relative intactness of visual-perceptual ability of the current DAT sample:

### **TABLE 1 ABOUT HERE**

### **2.3.2. Comment**

On the basis of data from Experiment 1, it can be argued that these DAT patients do not suffer from any visual-perceptual deficits that might prevent them from constructing a stable structural representation during visual object recognition. The next study involves an assessment of object naming ability of the same two groups of subjects.

## **2.4. Undegraded Picture-naming task**

### **2.4.1. Materials**

The object-naming stimulus set consisted of 40 images from a broad selection of categories which included tools, clothing, furniture, four-legged animals, birds, fish, amphibians, and rodents (see *Appendix A* for full list of items). The particular images used were rich in detail to ensure that systematic removal of features would not lead to a catastrophic decline in recognition as might happen with line drawings such as those of Snodgrass and Vanderwart [45]. Otherwise all depicted objects were among those found in the aforementioned corpus. All images were piloted with a group of six elderly people. Cut-off for inclusion in the stimulus set was name agreement in a minimum of 5/6 with the remaining subject giving a legitimate alternative name (e.g. mallard for duck).

Subjects were tested individually. They were shown one picture at a time, and asked, "Can you tell me what this is?" and their response was recorded. If they gave more than one response, they were asked to choose the one which they thought best labelled the object. The DAT group's naming errors were then classified by 9 independent, naïve judges, who categorised each naming error into one of 7 categories. A previously-established error categorisation scheme was adopted [46], although the definitions, but not necessarily the nomenclature of their categories correspond closely with those used by Hodges et al [21]. For comparison, the nomenclature of the Hodges et al. scheme [21], where different, is given in brackets.: (1) *superordinate*, if given name was the name of the item's category ("bird" for *sparrow*); (2) *semantic paraphasia(Category)* if the given name was a structurally dissimilar member from

the same taxonomic category (“spoon” for *saucepan*); (3) *visual semantic paraphasia*, if the given name was in the same semantic category as the target and shared visual features (similar outline, both being striped etc., such as “house” for *shed*); (4) *visual*, where the name was of a different semantic category to the target but shared some superficial visual features (“cash-till” for *telephone*); (5) *functional (Associative and Circumlocutory)*, whereby a description of the object’s functions and attributes was elicited (“play music” for *piano*); (6) *Non-response*, where no responses were given. Other responses were labelled *unrelated response*. In order for a classification of a particular error response to be acceptable, a minimum of 7/9 judges had to have assigned the response to the same error category.

#### **2.4.2. Results**

The mean correct object-naming score of the DAT group was 34.2/40 (S.D. 2.4), with the control group scoring 38.4/40 (S.D. 1.0). Results from this analysis suggest that the DAT group, as a whole, showed object naming deficits ( $F = 27.37$ , [1,18],  $P < 0.001$ ). Within the DAT group there was no relationship between error frequency and ratings for concept familiarity ( $r = 0.12$ ,  $p = 0.49$ ), visual complexity ( $r = 0.05$ ,  $p = 0.8$ ), or word-frequency ( $r = -0.24$ ,  $p = 0.16$ ). Naming errors coded are presented in Figure 1.

#### **FIGURE 1 ABOUT HERE**

#### **2.4.3. Comment**

As expected this group of mild DAT demonstrated a significant anomia. The pattern of errors could not be explained by word-frequency, visual complexity, or familiarity of the stimuli. However there is considerable similarity between error patterns found here, and that reported by Hodges et al [21]. Apart from non-responses, anomic errors tended to be either commission (i.e., within category), associative, or circumlocutory errors. This pattern of errors suggests that anomia in the DAT sample is likely to be due to deficits *either* at the structural level of processing, or at the semantic stage, or both. Indeed, a high proportion of naming errors involved visual-semantic paraphasia errors as well as functional errors; and whilst the latter seems to implicate the semantic stage of processing, the former error type may implicate the structural, *and/or* the semantic stage(s) of object processing. The available data does not permit an adjudication between these possible loci of deficits at this juncture. However, the error profile is not readily attributable to a disorder of visual sensory analysis since the patients performed to a very high standard on Efron’s shape matching and the subtests of the VOSP. It is also unlikely that the anomia resulted from a dysfunctional output lexicon since neither word frequency nor phonemic cuing improved performance.

#### **2.5. Degraded Picture Naming Task**

This study utilised the same images from the previous Experiment and systematically degraded them. It was hypothesised that if object recognition difficulties partly result from degraded structural knowledge, then a higher threshold of picture completeness would be required by the patients, in order to name the depicted object. However, since the word recognition scores for these patients on the NART were very similar to

those of the control subjects, we would expect a comparable threshold to controls for recognising degraded words, since letter/word recognition systems appear intact. However, if perceiving degraded stimuli per se is difficult, due to undersampling [42], then the threshold for word completeness will also be raised in patients.

### **2.5.1 Materials**

#### *2.5.1.1 Picture Stimuli*

The 40 images were the same images as those described earlier. For each image, five degraded versions of varying degrees of degradation were constructed, in order of increasing degradation. The aim was to remove high frequency or featural information, *without* distorting the global shape. Examples of degraded images of two entities are shown in *figures 2 and 3*.

#### **FIGURES 2+3 ABOUT HERE**

The above procedures led to construction of a total of 240 images (6 images – one undegraded version, and 5 degraded for all 40 entities). The images were then arranged in order from most degraded, to non-degraded.

#### *2.5.1.2 Word Stimuli*

Twenty words formed the basis of this task, and were taken from the Schonell Graded Word Reading Test (SGWRT) [44], which consists of words that can be successfully read by 7-8 year old children of average reading ability. The word stimuli once again underwent degradation such that several different degraded versions were constructed. In order to ensure that the degradation method used to construct the degraded word stimuli was equated for sensitivity in detecting threshold for identification, we carried out a pilot study with 3 healthy subjects (mean age 71.5 years). Varying degrees of degradation of 10 words from the stimulus set were presented to the subjects and the level of degradation at which 1/3 of subjects failed to recognise the word, was noted (the minimum threshold). Seven versions were then constructed for each word stimulus: one undegraded (level 1), and six increasingly degraded versions (levels 2-7). The minimum threshold from the pilot study was equated with level 4 degradation, where 7/10 controls made at least one error. Two examples are shown in *figure 4*.

#### **FIGURE 4 ABOUT HERE**

All seven versions of each word stimulus were laser printed on a single A4 sheet, with the individual versions arranged from most degraded, on top of the page, to not-degraded at the bottom of the page.

### **2.5.2. Method**

#### *2.5.2.1 Degraded SGWRT*

A previously used method of limits approach [49] was also adopted for this study. On each trial, all but the most degraded version of a word were covered, and



the subject was prompted to read the word, within a time-limit of 20 seconds. If no response was forthcoming, the card was moved down the page to reveal the next, less degraded, version of the word, and the subject tried again. This procedure continued until the subject was successful in reading out the word. As there were 7 versions of each word, the subject scored '7' if they were able to read the most degraded version, '6' if they could only read the next, less degraded word, etc. If they could only read the non-degraded version, they scored '1', and if unable to read even the undegraded version of the word, they scored zero (this did not happen on any trials).

#### 2.5.2.2 Degraded Object Naming Task

On three separate occasions marked by intervals of at least one day, and no more than three days, each DAT subject was asked to name the full set of 40 *undegraded* images. This was used to establish the item-to-item naming consistency. Thus, only the stimuli that were consistently named *correctly* (i.e. on all three occasions) had their degraded versions subsequently presented to the patients, for naming.

On the fourth occasion, the patients were again asked to name each depicted item. The most degraded version of the stimulus was shown and the subject was asked to attempt naming the item. Errors followed by immediate and unprompted self correction were considered correct. However, if the subject was unable to name the image within 20 seconds, the next, less degraded version, was shown, and the patient was asked to try again. If the patient was successful, the remaining degraded versions of that entity were not shown, and the task proceeded onto the next trial. As there were a total of 6 images for any one entity (5 degraded, 1 undegraded), the subject scored '6' if they could correctly name the most degraded image, '5' if they could correctly name the next, lesser degraded image. Successful naming of only the undegraded version scored '1'. Failure to name the undegraded image was scored as a zero.

#### 2.5.3. Results

On the Degraded SGWRT, out of a maximum score of 140, the control group scored a mean of 124.3 (S.D. 2.2), compared to the DAT group's score of 122.9 (S.D. 6.0); these were not significantly different ( $t(18) = 0.69, P = 0.502$ ) suggesting both DAT and control groups performed equally well in reading degraded words.

On the degraded object naming task, out of a maximum score of 240, the control group obtained a mean score of 212.2 (S.D. 4.8), and the DAT group obtained a mean score of 180.8 (S.D. 16.60); which was significantly different ( $t(18) = 5.749, P < 0.001$ ). Since the higher the score, the greater the ability of subjects in naming degraded images of entities, this suggests that the control subjects were able to name an entity at a higher level of degradation, compared to the DAT patients.

In order to assess whether the comparatively poor performance of the DAT patients could be related to variations in familiarity, visual complexity, and/or word frequency of the entities concerned, the mean level at which the DAT group could name degraded images of an entity was calculated for each item, and correlated with its object variables. Results revealed no significant correlations between the DAT naming degradation level of the item, and its familiarity ( $r = 0.14, P = 0.41$ ), visual complexity ( $r = -0.05, P = 0.78$ ), or word frequency ( $r = 0.22, P = 0.18$ ).

#### 2.5.4 Comment

This study assessed the ability of a group of DAT patients to recognise degraded pictures of objects which had been previously recognised, without error, in their normal, i.e. undegraded form. Compared to controls, DAT patients could only correctly name a depicted entity at a significantly lower level of image degradation (i.e., upon seeing a more intact image). The effect size for the group difference was 2.5 indicating a large effect of image degradation on DAT object recognition performance. The same was not found for word recognition. Degradation of words did not affect DAT patients any more than it affected the control subjects. The effect size of the group difference was 0.3. Thus, the claim that DAT anomia is *solely* due to *semantic* degradation would seem to be refuted. The implications of this assertion are examined next.

### 3. Discussion

These series of studies have investigated whether degraded structural descriptions contribute to visual object naming difficulty in mild DAT subjects. All 10 DAT subjects demonstrated a significant degree of picture naming impairment. It was assumed that those pictures which were consistently named correctly accessed relatively intact item-specific representations at three stages of visual object recognition: structural descriptions, semantic and output lexicon .

DAT naming error analysis indicated a predominantly semantic level deficit - i.e., few pure visual confusion errors and substantial numbers of intra category or associative/circumlocutory errors. This pattern can be explained by either the cascade model of object recognition [24] or interactive models of object perception [48]. In the cascade model error at one stage of the processing stream is propagated through the remainder of the processing stream. Therefore imprecise specification of a structural description can lead to commission or associative errors especially when there are shared features,. According to interactive models of object naming, processing at each stage of the naming system (i.e., perceptual, semantic, and phonological) is informed by outputs from the other stages. Erroneous output from any stage will influence output from all other stages. In the Tippett and Farah model [48], for instance, a single locus of impairment was sufficient to account for a wide variety of obtained data from object naming tasks. Only at extreme levels of degraded structural descriptions would pure visual errors be expected according to either model. Therefore one must question the validity of error analysis as a robust method for determining the locus of anomia.

Subsequently, in order to demonstrate that DAT naming errors were not *solely* due to semantic deficits, the subjects carried out a degraded picture naming task, in which they were asked to name degraded versions of the same pictured objects that they had consistently named correctly under normal viewing conditions. Compared to the controls, the DAT subjects needed a significantly less degraded, more intact image to be able to recognise and name the objects. It was argued that such impaired DAT degraded-image naming performance could not be attributed to *generalised* visual and/or cognitive deficits in processing degraded visual inputs, *per se*, since their recognition threshold for recognising degraded words was similar to that of the control subjects.

It is difficult to find an explanation for these findings in terms of partial degradation of representations in either the semantic system or output lexicon, since damage to the latter two components would also produce naming errors with complete, undegraded images. It is also unlikely that their performance could be explained by impairments at an early stage of visual processing, or by impaired visuo-spatial abilities, since performance was well within the normal range on the screening tests. The finding of impaired structural descriptions of objects with relatively intact early visual processing in AD have been previously reported [20]. Thus we have concluded that there must be some low level of degradation to the structural description system, even for items which are named correctly. If this is the case then more structural information from the visual display would be required in order to activate item specific structural descriptions.

A possible, alternative explanation could be that the DAT patients were 'undersampling' [42] such that only a portion of all salient features, or signals, inherent in the pictorial form, are processed. Thus, it could be argued that if the degradation technique reduces the number of salient features that could be perceived from the display, then a subject who was undersampling would only recognise a picture at a lower level of degradation. However, such an explanation would apply equally to word recognition. Yet, as demonstrated by the DAT performance on the degraded SGWRT task, the degraded-word recognition threshold was similar in both DAT patients and normal controls, such an explanation would seem untenable. In conclusion, we propose that the DAT ability in correctly naming visually presented objects is not necessarily indicative of an intact structural representation system. Arguments concerning the flow of information in cascade through the various levels of the object naming stages, in which inadequate processing at the structural level would be augmented by additional processing at the semantic system, together with the results of the present study, would suggest some caution in interpreting object naming data from DAT patients.

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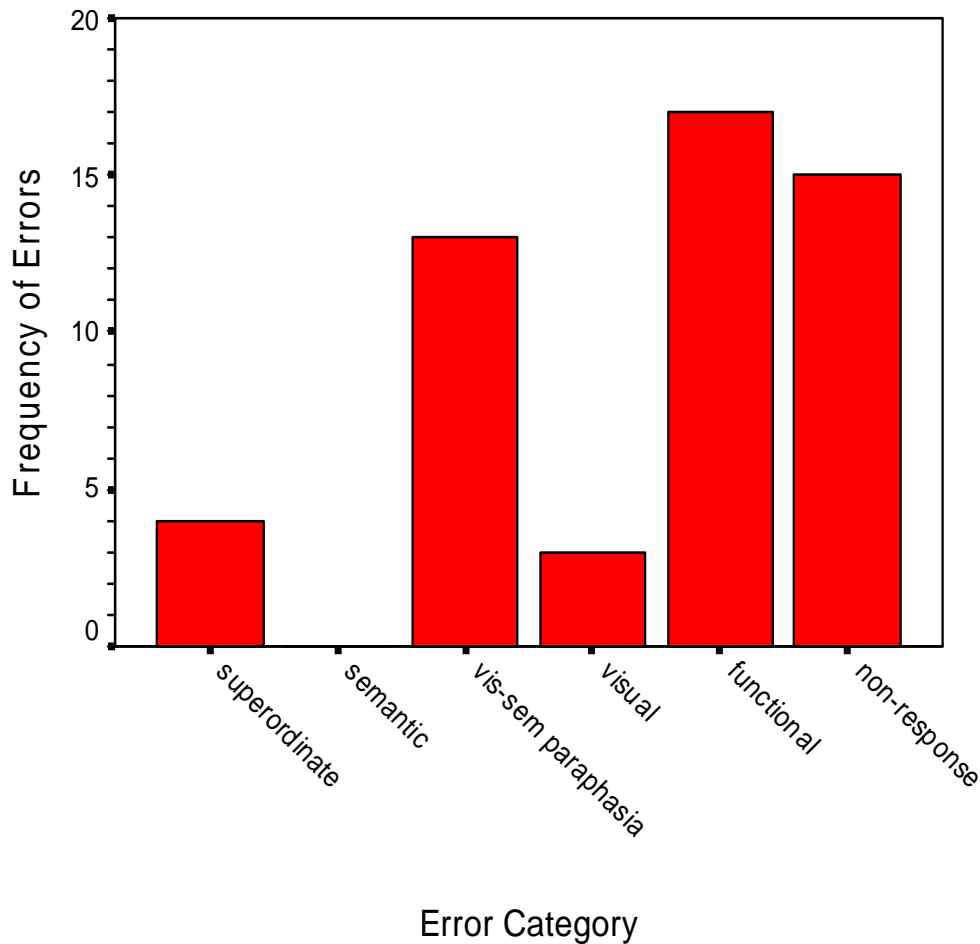
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**Table 1**  
**Visual-perceptual Tests**

Test (max score)	DAT( <i>n</i> =10)		Control( <i>n</i> =10)		<i>t</i> -test ( <i>P</i> -value)
	Mean	S.D.	Mean	S.D.	
Efron shape-matching (7)	7.0	0.0	7.0	0.0	N/A
Figure Copying (4)	3.5	0.5	3.6	0.5	0.67
Dot Counting (10)	9.2	1.1	9.7	0.5	0.21
Position Discrimination (20)	18.8	1.6	19.3	0.8	0.38
Number Location (10)	6.9	1.5	7.6	0.8	0.22
Cube Analysis (10)	9.0	1.6	9.4	0.9	0.50
Unusual Views Test (13)	12.0	1.1	11.6	1.4	0.49

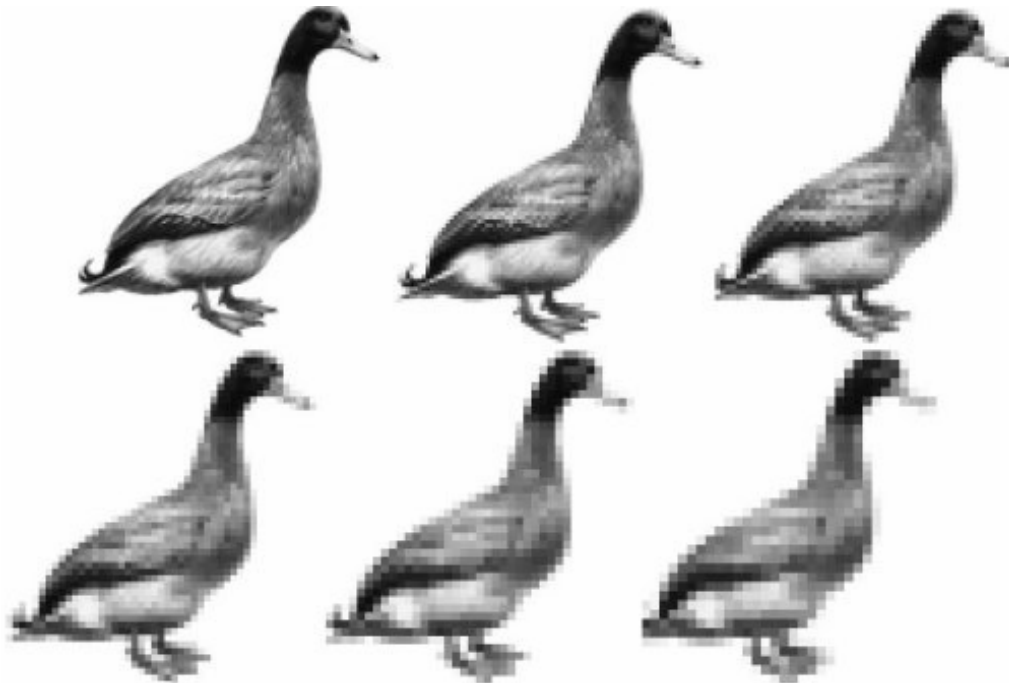
Patients (DAT) and controls in visual-perceptual tests. Between groups comparisons were performed by independent-samples *t*-tests.

**Fig. 1.**



**Fig. 1.** Frequency of object naming errors in the DAT group, in terms of Error Category

**Fig. 2.**



**Fig. 2. undegraded ‘Duck’, and five degraded versions (clockwise from top left: undegraded, degraded 2, degraded 4; degraded 6, degraded 8, and degraded 10).**

**Fig. 3.**



**Fig. 3: undegraded ‘Wristwatch’ and five degraded versions (clockwise from top left: undegraded, degraded 2, degraded 4; degraded 6, degraded 8, and degraded 10).**



Fig. 4.

Flower	Light
Flower	Light
Flower	Light
Flower	Light
Flower	Light
Flower	Light
Flower	Light

Fig. 4. Two exemplars of degraded word-stimuli, each consisting of one undegraded version (bottom) and 6 increasingly less degraded versions (uppermost word = most degraded).

**Appendix A**  
**List of concepts used in the object-naming tests**

<b>Entity</b>	<b>Familiarity</b>	<b>Visual Complexity</b>	<b>Word Frequency</b>
Bear	2.86	2.57	57.00
Cat	5.43	3.00	23.00
Chicken	5.40	2.20	37.00
Cow	5.20	2.20	29.00
Deer	3.71	3.29	13.00
Dog	5.80	2.00	75.00
Duck	4.43	3.29	9.00
Fish	4.86	3.71	35.00
Gerbil	3.43	3.29	0.00
Horse	4.71	3.14	117.00
Lizard	2.14	3.57	1.00
Monkey	3.14	3.14	9.00
Parrot	3.00	3.57	1.00
Pig	4.00	3.00	8.00
Rat	4.43	3.29	6.00
Sheep	4.80	2.40	23.00
Sparrow	5.20	2.00	1.00
Turkey	4.60	2.80	9.00
Turtle	2.71	3.29	8.00
Wolf	3.00	3.43	6.00
Anorak	4.43	2.29	0.00
Binoculars	3.29	4.00	2.00
Briefcase	4.86	2.14	1.00
Calculator	4.71	2.43	1.00
Camcorder	2.80	4.80	0.00
Camera	4.57	3.86	36.00
Dress	4.57	2.29	67.00
Iron	4.86	2.86	43.00
Ironing board	4.86	2.00	0.00
Piano	2.20	4.00	38.00
Pram	2.60	4.20	1.00
Saucepan	4.71	2.29	3.00
Shaver	3.57	2.43	0.00
Shed	4.00	2.57	11.00
Spade	4.86	1.57	10.00
Table lamp	4.86	2.57	0.00
Telephone	5.86	4.00	76.00
Typewriter	3.80	4.60	10.00
Vacuum cleaner	4.71	2.00	0.00
Wristwatch	5.14	3.57	2.00

**Showing Familiarity, Visual Complexity, and Word frequency ratings for the full set of Stimuli.**