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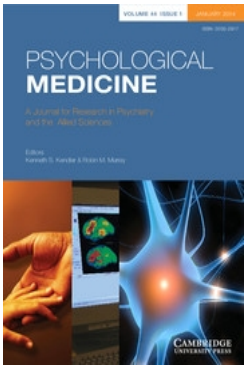

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A cancellation test: its reliability in assessing attentional deficits in Alzheimer's disease

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SYNOPSIS The aim of the study is to provide (i) a standardized procedure for a Cancellation Test of Digits, designed to assess in the visual modality selective attention deficits in patients with Alzheimer's disease, and (ii) a detailed analysis of how patients cope with it.

Age-, education-, and sex-adjusted normative scores earned by 352 healthy controls are set forth, as well as data yielded by the Digit Cancellation Test in 74 Alzheimer patients, in 26 patients with a CT-assessed frontal lobe lesion and in a group of 24 healthy subjects urged to perform the task with a shortened time-constraint. Findings include discriminant power of Alzheimer patients *versus* healthy controls, sensitivity to cognitive evolution of the dementing process and analysis of errors. Attention data failed to supply psychometric support for the posterior-to-anterior algorithm of progressive cortical encroachment of Alzheimer's disease suggested by PET-findings.

Emphasis is put on methodological aspects of neuropsychological research on Alzheimer patients and on the analysis of processing components of the tests employed. Results are discussed in the light of the relationships between psychometric assessments and related functions, and underlying neuronal degeneration.

INTRODUCTION

The role of attention disorders in the cognitive breakdown of Alzheimer's disease (AD) is still insufficiently studied and poorly understood (Jorm, 1986; Spinnler, 1991). Given the protean and content-independent nature of attentional control and its conceptualizations (Kahneman, 1973; Schneider & Shiffrin, 1977; Hasher & Zacks, 1979; Reason, 1984; Wickens, 1984), psychometric tools are always at risk of being theoretically ill-framed and arbitrarily devised. Further difficulties arise from the fact that AD is a progressive condition, with an extremely heterogeneous cognitive profile (Capitani *et al.* 1986; Martin *et al.* 1986; Baddeley *et al.* 1991*a*). In these circumstances it is essential to describe patients and psychometric tools with great care, and subject experimental data to strict statistical evaluation if we are to reach inferential conclusions.

Performance on tests that are said to carry a high attentional load, such as forward span of immediate memory, is held to be sometimes preserved, and often only mildly impaired, in the early stages of AD (see Morris & Baddeley, 1988 for a review). On the other hand, there are other aspects of attention, such as selective attention in visuo-spatial memory (Stuart-Hamilton *et al.* 1988) or in semantic judgement tasks (Nebes *et al.* 1989), divided attention tasks in dichotic tests (Caird & Inglis, 1961; Grady *et al.* 1989) and selective focused attention in a visuo-perceptual figure-ground discrimination test (Capitani *et al.* 1988), on which performance has been shown to be impaired at an early stage in a substantial number of AD-patients (AD/pts). Furthermore, the 'Central Executive' component – the attentional loaded component of Working Memory (Baddeley, 1986) – appears to be early involved in virtually all AD/pts (Baddeley *et al.* 1986, 1991*b*; Morris & Baddeley, 1988). The un-

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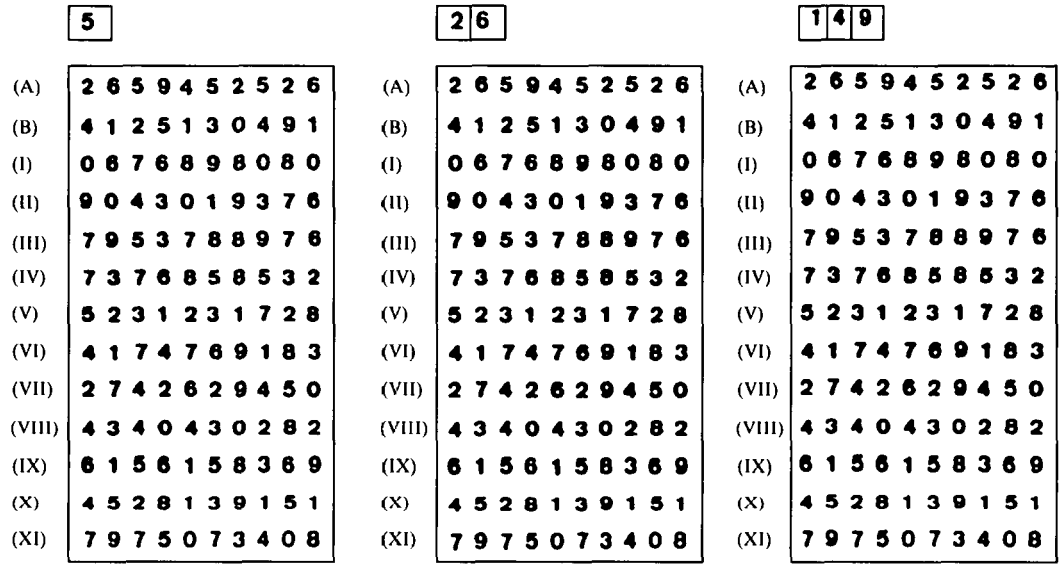

FIG. 1. The three different matrices of the Digit Cancellation Test (oDCT) target digits are printed at the top of each matrix. Length of longest side of each rectangle is 20·5 cm.

certainty surrounding the relevance of attentional deficits to the impairment of a large number of neuropsychological performances in dementia (Spinnler, 1991) increases the need for psychological tools whose psychometric features have been thoroughly studied and critically evaluated.

One of the facets of attentional control is selective attention (review in Parasuraman & Davies, 1984). Timed tasks of selective cancellation of digits (Lewis & Kupke, 1977, quoted by Lezak, 1983), letters (Talland & Schwab, 1964) or patterns gave rise to classic tests, having all the advantages of being easily grasped and carried out by brain damaged patients. These tests are generally agreed to measure the resources available to support performances chiefly involving selective focused attention (Lezak, 1983; Tenber, 1964). Fitting such tests into a facet of the attentional taxonomy is, however, mostly a matter of how the tests are administered. So, cancellation tests can also be used to assess sustained attention (Bruggeman *et al.* 1989) and, as in the present case, a digit cancellation test can arguably yield measures of divided attention. The attentional characteristic of such tasks though rests on the face-value evidence of a contrast between apparent attentional demands and apparently low demands on any other cognitive ability (Spinnler, 1991). The time constraint of these tasks compels the subject to manage the speed/accuracy trade-off, another feature associated with the attentional control. Admittedly this reasoning is based on the performance of healthy subjects (H/Ss), and is tacitly extended to brain-damaged patients such as those suffering from AD.

Spinnler & Tognoni (1987) presented an *original* standard version of a digit cancellation test (*oDCT*) suitable for assessing selective attention deficits in demented patients. The score adopted for oDCT was an overall hit-score, which did not allow for possible biases likely to occur in AD/pts, such as perseveration. The impact of such a bias on the hit-probabilities would change across the 3 matrices making up the original test material (Fig. 1).

In Spinnler & Tognoni's (1987) study, the intuitive assumption of an increase of the attentional load from the first to the third matrix was not verified, and it was not possible to ascertain in that study on normals whether the 3 matrices discriminated H/Ss and AD/pts differently.

This investigation presents a *new* version of the DCT (*nDCT*) and the outcome of its use on AD/pts. The aim of this study on nDCT is threefold, namely (i) to establish normative

data, and to check its total predictive value between AD/pts and H/Ss, as well as its sensitivity over a half-year period to the psychometric worsening predicted to occur in the course of AD; (ii) to find out whether nDCT, in combination with other tests, could provide psychometric evidence of the posterior-to-anterior evolution of AD-encroachment on the cortex, suggested by PET-studies (review in Pawlik & Heiss, 1989); (iii) to provide a clue as to the sequence of actions through which AD/pts are likely to carry out a cancellation task such as nDCT.

METHOD

Alzheimer's disease patients (AD/pts)

The study sample was the outcome of the process of selection set out in Fig. 2: (i) between March 1985 and February 1988, 328 patients were referred by general practitioners or neurologists or psychiatrists to one or other of our two out-patients Dementia Research Units (S. Paolo University Hospital, Milan; Medical Center, Veruno) because of suspected dementia; (ii) in 241 of them the diagnosis of dementia (Spinner & Della Sala, 1988) was confirmed; (iii) in 145 of them the diagnosis of probable AD was established according to formal criteria (Della Sala *et al.* 1986) broadly in line with those of the NINCDS-ADRDA (McKhann *et al.* 1984); (iv) in 76 of them AD was considered mild to moderate according to the DSM-III-R (American Psychiatric Association, 1987) and Hughes *et al.*'s (1982) criteria. We tried to use the criteria set out in DSM-III-R (and also those of

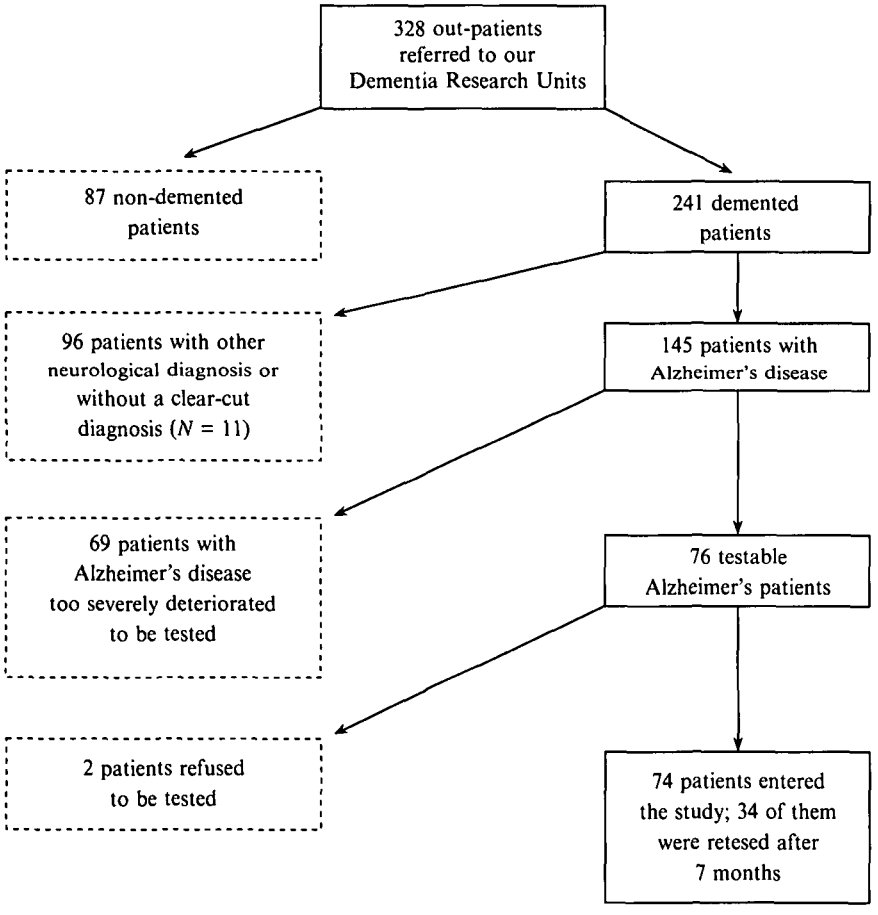

FIG. 2. Flow-chart of the selection steps of the patients suffering probable Alzheimer's disease who entered the study.

Table 1. *Features of the patients suffering Alzheimer's disease who entered the study (Test), who were retested (Retest) and features of the patients who dropped out*

	Test AD/pts (N = 74) Mean (S.D.)		Retest AD/pts (N = 34) Mean (S.D.)	Drop out AD/pts (N = 40) Mean (S.D.)
Age at onset (years)	60·70 (6·8)		60·41 (6·17)	60·95 (7·36)
Age at testing (years)	63·35 (6·96)		62·76 (6·30)	63·45 (7·48)
Length of illness (months)	29·34 (19·41)		28·50 (17·43)	30·05 (21·15)
Educational level (years)	7·69 (4·33)		7·91 (4·84)	7·28 (4·61)
Male/Female frequencies	29 M 45 F		16 M 18 F	13 M 27 F
Inter-test interval (months)		7·72 (3·62)		

Hughes *et al.* 1982) in order to separate 'mildly' from 'moderately' deteriorated AD/pts. A great contrast across observers, as well as a substantial number of unselected AD/pts turned out, even if there were many clear-cut cases, particularly at the 'mild' extreme. So we decided not to differentiate between the two classes, since we deemed the above mentioned criteria insufficiently stringent to accomplish the aim. Besides overall severe cognitive impairment, causes of exclusion of AD/pts at this stage were concomitant neurological or internal disorders (viz. liver, kidney, lung and thyroid chronic failure; anaemia and cancer), pre-dementia pharmacologically treated psychiatric disorders, history of alcohol abuse or chronic intake of drugs likely to affect cognitive efficiency. Two other patients were excluded because they refused neuropsychological testing. Table 1 gives the characteristics of the 74 patients (45 females and 29 males) entering the study, making up only 51% of the overall probable AD candidates. All AD/pts were able to perform on nDCT. Thirty-four of these patients (18 females and 16 males) agreed to undergo a second neuropsychological examination after an interval of approximately 6 months. The characteristics of the patients tested a second time and of the drop-outs are also shown in Table 1. None of the variables taken into consideration differed significantly between these two subgroups: the t values (df = 72) were all less than 1, and the contingency table concerning sex distribution yielded a χ^2 of 1·635 (df = 1, NS). This rules out the possibility of a selection bias in the follow-up group, in particular this rules out selective attrition of deteriorating patients as a plausible interpretation of our results.

Control subjects

(*i*) *Healthy control subjects (H/Ss)*

nDCT was administered to 352 healthy subjects aged from 20 to 99 years, 157 males and 195 females. The subjects were check-listed to exclude brain diseases, heavy alcohol or psychotropic drug intake, metabolic disorders, kidney, liver, lung or thyroid failure; no laboratory assessment was carried out. Age and education of the H/Ss are as follows: mean age 61·88, S.D. 16·8 (range 20–99), and mean education 8·23, S.D. 4·49 (range 1–18). In order to recalculate normative values for nDCT, the data of the same 321 subjects employed for the oDCT standardization (Spinnler & Tognoni, 1987) were reconsidered.

(*ii*) *'Stressed' healthy subjects (sH/Ss)*

Twenty-four healthy control subjects (12 males and 12 females) underwent a nDCT within a shortened time limit of 10 s (see procedures). Their mean age is 40·2 (S.D. 14·54, range 21–68) and their mean education 11·7 years of schooling (S.D. 4·61, range 5–17). They were included in the study in order to verify if the quality of errors of a group of normals performing the task with a more difficult procedure would be of the same type or of a different type with respect to errors of the pathological groups.

(*iii*) *Patients with frontal lobe lesions (F/pts)*

nDCT was also administered to 26 patients (15 males and 11 females) with a CT-assessed frontal lobe lesion (12 with a left and 8 with a right unilateral lesion, 6 with a bilateral lesion) who entered the study as brain-damaged control subjects. They are 25 to 77 years old with 3 to 17

years of education (mean age 51·46, S.D. 12·11 and mean education 8·23, S.D. 4·29). Selection criteria of these brain-damaged patients included having a definite frontal lesion assessed by CT-scan and a congruent neurological or neuro-surgical history. Moreover, they did not show any ecological symptoms pointing to dementia. The patients' willingness to undergo testing was required. The aetiology of the frontal lesions varied widely and this was not a criterion of inclusion/exclusion in the study. They were included in the study in order to compare the quality of their errors with those of AD/pts.

Testing procedures and scoring methods of the new version of Digit Cancellation Test (nDCT)

In oDCT (Spinnler & Tognoni, 1987), as in all other digit cancellation tests, digits had to be crossed out within a time-limit, in this case 45 s/matrix. Three different matrices were made up of 13 strings of 10 digits each (Fig. 1). The digits used in this test are from 0 to 9 in random sequence. The first line of each matrix serves as an example, the second line serves as a 'run-in' trial. The other 11 lines of digits make up the text. Each line includes from zero to five targets. The task was to detect and pencil out each target digit the subject could identify. The target was only one digit for the first matrix, two for the second and three for the third. There was no interpolated time or distraction between matrices except to brush up the instructions. The examiner explained that each matrix had to be scanned, line by line, from left to right ('as if reading'), and from top to bottom. This was done with the help of example and run-in lines. The examiner pointed to the target printed at the top of each matrix. Failure to obey these instructions was not corrected during the test. Scanning by means of the finger- or pencil-tip was not allowed. Score was given in overall hits, that is the number of corrected targets crossed out within the time constraint. This was the original version of DCT (Spinnler & Tognoni, 1987).

The new version (i.e. nDCT) devised for this study on the basis of the discriminant powers of each matrix between AD/pts and H/Ss (see Results section), provided two variations of the procedures: (i) the 1-digit target matrix acted as a buffer-trial, and test-scores turned out from the 2- and 3-digits targets matrices; (ii) since the number of possible hits is different for each test-matrix (respectively 20 and 30), the probability of choosing a correct target digit by chance increases from the 2- (18%) to the 3-digit target matrix (27%). One point was assigned for each hit response, and a negative coefficient was calculated for each 'false alarm' (viz. a non-target digit crossed out) as follows: $-20/90$, that is $-0{\cdot}22$, for the 2-digit target matrix, and $-30/80$, that is $-0{\cdot}37$, for the 3-digit target matrix. These negative scores are subtracted from the hit scores. The score ranges were respectively 0–20 and 0–30, which makes an overall range of 0–50. In this way an experimental subject who had crossed out every digit (targets and non-targets) would achieve a 0-score (instead of a best score, as in the oDCT). For instance, in the 2-target matrix he would have achieved $+20$ points for having crossed out all the targets (the maximal hit score being 20) and -20 points for having crossed out all the non-targets (the maximal 'false alarm' score being about -20, viz. $-0{\cdot}22 \times 90 = -19{\cdot}8$).

For some analyses it was also necessary to take into account the data of the first matrix: in which case the negative coefficient for each false alarm was $-0{\cdot}10$ ($-10/100$).

The above-mentioned were the standard procedures. In order to cast some light on the analysis of errors, the small experimental group of 'stressed' healthy subjects (sH/Ss) ran the test with a 10 s time-constraint for each matrix.

Other neuropsychological variables

From a large neuropsychological test battery (Capitani *et al.* 1990) a 6-test set was chosen. It was made up of 2 tests of control or 'general' function, viz. a logical non-verbal intelligence test, Raven's Progressive Matrices, set A, B, C and D (1938) and a Goldstenian abstract thinking task, i.e. Weigl's Sorting Test (1927), following Spinnler & Tognoni's (1987) version; and of 4 tests addressing so-called 'instrumental' functions, viz. a two-dimensional constructional apraxia test (Arrigoni & De Renzi, 1964), a test of episodic memory (a 10 disyllabic word-learning test, following the Buschke-Fuld, 1974, selective reminding technique), a test of oral comprehension of sentences (Token Test; De Renzi & Vignolo, 1962) and a test of visual

perception (Street's Completion Test; Street, 1931). Admittedly, the control/instrumental test-distinction is rather crude (Spinnler, 1991), and will be discussed later. Procedures and scoring of all these tests are detailed in Spinnler & Tognoni (1987); age-, sex- and education-adjusted normative data are set forth in the same study. As this is a retrospective study, scores on the above-mentioned tasks proved to be available for only 49 out of 74 AD/pts; there is no apparent selection bias at work as the reduced number of AD/pts depended only on factors due to work organization.

RESULTS

Results are described under the following headings: (i) how the new version of DCT works on AD/pts, and normative data for it; (ii) psychometrical evidence of the posterior-to-anterior evolution of the cortical AD-encroachment; (iii) analysis of the errors made by AD/pts, F/pts and sH/Ss. Statistical procedures will be described for each of the questions covered.

(i) nDCT in H/Ss and AD/pts; normative data

Increase in attentional load

In order to verify our assumption that the 3 subtests of oDCT impose an increasing attentional load, we looked for a decline in performance from the 1-digit target to the 3-digit target matrix. Performance was scored using the new method described above (nDCT).

To do this, we used the whole samples of 352 H/Ss and of 74 AD/pts. As our purpose here was only to compare the scores earned on the 3 matrices of nDCT we decided not to take into account age, sex or education, even though they are known to influence oDCT performance (Spinnler & Tognoni, 1987). For each sub-test we chose the score corresponding to the one-sided external non-parametric tolerance limits for 95% of the population with 95% confidence (Wilks, 1941) as cut-off. Then for each matrix we calculated how many AD/pts fell below the cut-off score, and compared these percentages.

In Table 2 mean nDCT-scores achieved for each matrix by H/Ss and AD/pts, cut-off scores and AD/pts falling them below them are set out. We calculated the confidence limits of the percentages below the cut-off through the analysis of likelihood profiles (Aitkin *et al.*1989). For the first matrix the confidence limits were: 18% to 39%; for the second: 37% to 60%, and for the third: 40% to 63%. These confidence limits suggest that the second and third matrices are harder than the first, although the limits of the first and second overlap slightly. On the other hand, the increase in 'difficulty' from the 2- to the 3-digit target matrix is marginal. It is on this evidence that the 2 test-matrix nDCT was devised in place of the 3 test-matrix oDCT; further evidence on this issue was achieved by data given in the next heading.

Table 2. *Mean nDCT scores earned on the* 1-, 2- *and* 3-*target digit matrix by Healthy Subjects (H/Ss) and by patients with Alzheimer's disease (AD/pts). Cut-off scores and number of AD/pts falling below them are set out*

	Matrices		
	1-target digit (score range 0–10) Mean (S.D.)	2-target digit (score range 0–20) Mean (S.D.)	3-target digit (score range 0–30) Mean (S.D.)
H/Ss ($N = 352$)	9·10 (1·31)	16·52 (3·24)	22·74 (6·53)
AD/pts ($N = 74$)	7·07 (2·80)	9·49 (5·36)	8·96 (6·59)
Cut-off scores	6/10	9/20	8/30
Number of AD/pts below cut-off score	21 (28%)	36 (49%)	38 (51%)

Healthy/demented discrimination

The next step was to find out which matrix or combination of matrices achieved the best discrimination between AD/pts and matched H/Ss. All 74 AD/pts were included in this evaluation. For each of these AD/pts we selected from the pool of 352 H/Ss a subject who could be matched for age (±3 years), education (±1 year) and sex.

Taking the scores earned by AD/pts and matched controls on the first, second and third matrix of oDCT (scored following nDCT rules), we looked for the best discriminant between the two experimental groups. A discriminant analysis was run by means of a logistic regression, with the group as the dependent variable and the scores obtained on the three matrices as model variables. The latter were considered separately both one at a time and after partialling out the overlap with the remaining two. The differences

of the scaled deviances obtained from this logistic regression are distributed as chi-squares.

The mean scores earned by AD/pts and their controls on the 3 matrices are set out in Table 3,

Table 3. *Mean scores earned by 74 patients with Alzheimer's disease and 74 matched controls, on the 1-, 2- and 3-target digit matrix. Scores are assigned following the nDCT procedure*

	AD/pts Mean (S.D.)	Matched controls Mean (S.D.)
1-target digit matrix (score range: 0–10)	7·07 (2·80)	9·01 (1·22)
2-target digit matrix (score range: 0–20)	9·49 (5·36)	16·80 (2·73)
3-target digit matrix (score range: 0–30)	8·96 (6·59)	22·16 (6·65)

Table 4. *Logistic regression analysis. Each matrix score is considered 'alone' and after partialling out the influence of the other scores ('adjusted'). Scores are assigned following the nDCT procedure*

	'Alone' CHISQ (df)	*P*	'Adjusted' CHISQ (df)	*P*
1-target digit matrix	28·951 (1)	< 0·0001	0·845 (1)	NS
2-target digit matrix	78·618 (1)	< 0·0001	9·369 (1)	0·002
3-target digit matrix	90·528 (1)	< 0·0001	21·320 (1)	< 0·0001

and the results of the logistic linear regression analysis are set out in Table 4.

It turns out that each matrix discriminates significantly between H/Ss and AD/pts; however, only the 2- and 3-digit matrices are still discriminant after adjustment for overlapping. Since both contribute independently to the increase in the discriminant power between matched controls and AD/pts, we decided – as detailed under scoring procedures – to use the sum of the scores on the 2- and 3-digit target matrices as the new overall nDCT-score.

Healthy nDCT baseline

For the nDCT overall score we computed the age-, education- and sex-related normative data. In Table 5 mean nDCT scores earned by H/Ss and the best fitting statistical model are set forth.

All H/Ss entered the study. The influence of age, education and sex was studied through a covariance linear model. The effect of each variable was evaluated within the complete model, partialling out the effect in common with the other variables.

Age was found to be best represented as the square root of 100 minus age in years and its adjusted F value was 53·564 (df = 1,348, $P < 0·001$); education was most effective when transformed into log of years of schooling and its adjusted F value was 58·969 (df = 1,348; $P < 0·001$); sex was also found to be significant with $F = 10·024$ (df = 1,348, $P < 0·005$).

Table 5. *Mean nDCT overall score earned by healthy subjects distributed by sex and education. This is the overall 2- and 3-target digit matrix score with a 0–50 range (see text). Best-fitting statistical model, including education, is set forth*

Age	Males ($N = 157$) Mean (S.D.)	Females ($N = 195$) Mean (S.D.)	Low education (≤ 8 years, $N = 224$) Mean (S.D.)	High education (> 8 years, $N = 128$) Mean (S.D.)
20–29	48·30 (2·08)	48·00 (1·10)	48·5 (1·77)	48·06 (2·28)
30–39	46·50 (3·53)	43·00 (0)	46·5 (3·54)	46·67 (3·21)
40–49	43·63 (7·74)	43·94 (5·86)	43·09 (7·03)	45·0 (6·12)
50–59	42·55 (8·83)	39·69 (7·81)	37·84 (9·11)	45·0 (4·28)
60–69	42·23 (6·91)	38·53 (8·43)	39·74 (8·41)	41·61 (6·95)
70–79	39·34 (7·65)	33·38 (8·01)	35·50 (8·22)	40·72 (6·62)
80–89	29·64 (11·37)	31·41 (9·28)	28·05 (9·73)	36·98 (5·91)
90–99	31·95 (7·23)	31·00 (7·45)	31·53 (7·03)	38·0 (0)
Mean score for sex and education	41·37 (8·53)	37·57 (9·02)	36·95 (9·51)	43·30 (6·26)
Mean overall score		39·26 (8·99)		

Statistical model: y (i) = 39·26 + 2·214 [$\sqrt{}$ (100 − age (i)) − 6·018] + 5·385 (log education (i) − 1·945) + (+ 1·214 if male) or (− 1·214 if female). y (i) indicates the expected score for the i-th subject.

Table 6. *Adjustment to be added to (or subtracted from) the original overall nDCT scores according to age, education and sex of a given subject*

Education (yr)		Age (yr) 25	35	45	55	65	75	85	95
3	M	−2·5	−1·2	0·2	1·8	3·6	5·6	8·1	11·7
	F	−0·1	1·2	2·7	4·2	6·0	8·0	10·5	14·1
5	M	−5·3	−3·9	−2·5	−0·9	0·8	2·8	5·3	9·0
	F	−2·8	−1·5	−0·1	1·5	3·2	5·3	7·8	11·4
8	M	−7·8	−6·5	−5·0	−3·5	−1·7	0·3	2·8	6·4
	F	−5·4	−4·0	−2·6	−1·0	0·7	2·7	5·2	8·9
13	M	−10·4	−9·1	−7·6	−6·1	−4·3	−2·3	0·2	3·8
	F	−8·0	−6·6	−5·2	−3·6	−1·9	0·1	2·6	6·2
17	M	−11·8	−10·5	−9·1	−7·5	−5·8	−3·7	−1·2	2·4
	F	−9·4	−8·1	−6·7	−5·1	−3·3	−1·3	1·2	4·8

For each subject an adjusted score was calculated, by adding or subtracting the contribution of the significant concomitant variables from the original score. Table 6 lists the adjustments to be made on the original nDCT overall scores according to age, education and sex.

Adjusted scores were then ranked in ascending order. We used a non-parametric procedure (Wilks, 1941) to set tolerance limits to find the value of the one-sided 5th centile of the population. In this way we find both the 'external' tolerance limit (i.e. the observation whose score is the worst score achieved by *at least* 95% of the population, i.e. beta $(t) > 0{\cdot}95$) and the 'internal' tolerance limit (i.e. the observation whose score is the worst score achieved by *at most* 95% of the population, i.e. beta $(t) < = 0{\cdot}95$). Table 7 shows external and internal tolerance limits.

Table 7. *External and internal one-sided non-parametric tolerance limits for* 95% *of the healthy population with a confidence of* 95%

	Observation	Score
External limit, $\beta\ (t) \geqslant 0{\cdot}95$	11th	24·0
Internal limit, $\beta\ (t) \leqslant 0{\cdot}95$	26th	27·5

In this way, the 'external' tolerance limit defines the risk implicit in declaring a subject 'not normal', and the 'internal' limit controls the risk of declaring a subject 'normal'. The score-interval between the two limits is a region where decisions regarding normality are not statistically warranted.

In order to prevent errors due to the fixed scale limits of the test, we decided (i) never to adjust scores at the top-end of the scale, and (ii) to classify the adjusted scores into five categories (Equivalent Scores) with an ordinal relationship. For further details about this method the reader is referred to Capitani & Laiacona (1988). Table 8 gives the Equivalent Scores lay-out.

Table 8. *Equivalent scores: ranges of the adjusted score, number of healthy subjects located within each limit value (density) and their cumulative frequency*

Equivalent score	Range	Density	Cumulative frequency
0	0 to 23·9	10	10
1	24·0 to 29·8	26	36
2	29·9 to 36·2	57	93
3	36·3 to 40·4	81	174
4	40·5 to 50	178	352

AD/pts longitudinal data

We then checked the nDCT longitudinal modifications compared with those on the other tests (see below). Thirty-four AD/pts underwent a second examination at 7·72 (S.D. 3·62) months from the first. They were also given Raven's Progressive Matrices (PM), Token Test (TT), Weigl's Sorting test (WS), Constructional Apraxia (CA), Supra-span Verbal learning according to Buschke and Fuld's procedure (BF),

and Street's Completion test (SC). The aim of this was to search for longitudinal cognitive modifications due to the degenerative progression of AD. To compare the performances of the two test sessions we used a paired *t*-test. The mean scores of the tests at first and second examination and the relative *t* values are set forth in Table 9.

Table 9. *Mean scores earned on neuropsychological tests by patients with Alzheimer's disease (N = 34) on the first (Test) and second (Retest) assessment with the relative* t *values*

	Test Mean (S.D.)	Retest Mean (S.D.)	*t*	df	*P*
nDCT	19·98 (10·94)	17·49 (10·94)	1·62	33	NS
PM	15·25 (8·54)	10·59 (8·87)	3·27	33	< 0·01
WS	5·47 (3·42)	4·69 (3·09)	1·73	33	NS
TT	26·81 (5·89)	20·77 (8·23)	3·88	33	< 0·001*
BF	39·34 (31·22)	34·06 (29·31)	1·17	33	NS
CA	8·88 (4·26)	7·47 (4·37)	3·07	33	< 0·01
SC	4·56 (2·69)	4·03 (2·44)	1·43	33	NS

Key: nDCT = new version of Digit Cancellation Test (range 0–50); PM = Raven's Progressive Matrices, 1938 (range 0–48); WS = Weigl's Sorting Test (range 0–15); TT = Token Test (range 0–36); BF = Buschke Fuld supraspan word-learning test (range 0–180); CA = Constructive Apraxia (range 0–14); SC = Street's Completion Test (range 0–14).

* The significance level chosen according to Bonferroni's adjustment for non-independent multiple comparisons is 0·05/7 = 0·007; henceforth only *P* with asterisk has to be considered as significant.

The decline of performance reached the chosen significance level only on TT. On the other tests (including nDCT) the score difference, when adjustment for non-independent multiple comparisons is considered, was not significant. It is worth underlining that there is no difference on nDCT between re-tested ($N = 34$) and drop-outs ($N = 40$) AD/pts, namely mean scores of 19·98 (S.D. 10·94) and 18·24 (S.D. 11·33) respectively ($t < 1$; df = 72; *P*: NS).

Rôle of onset age and length of illness on AD/pts performance

We expected nDCT scores to be sensitive to length of illness and behavioural onset-age. The assumption was that nDCT-scores are sensitive to length of illness as a consequence of the PET suggested, progression of the encroachment of the AD-process from the more posterior areas to the more anterior. Furthermore, it may be that early onset age entails an earlier drop in nDCT-scores, due to the possibly quicker course of the disease in these AD/pts (Capitani *et al.* 1990). The whole original sample of AD/pts ($N = 74$) entered this analysis. The influence of these two parameters was assessed by means of a multiple regression with length of illness and onset-age as independent variables and the adjusted scores on nDCT as dependent variable. Results are shown in Table 10. Neither length of illness nor onset-age affected nDCT scores significantly.

Table 10. *Influence on the performance on nDCT of length of illness and behavioural onset-age*

	Mean (S.D.)	*F* (df)	*P*
Length of illness	29·34 (19·41)	1·197 (1,72)	NS
Onset-age	60·70 (6·8)	2·881 (1,72)	NS

Pattern of correlations

To check the psychological structure of nDCT, we took into consideration the psychometric consistency of nDCT with other tests. We computed the product moment coefficients, which are set forth in separately ranked orders for H/Ss and AD/pts in Table 11.

Table 11. *Partial correlations between nDTC-score and scores earned on the other neuropsychological tests in healthy subjects and patients with Alzheimer's disease. Tests are ranked according to the degree of correlation*

Test	Product moment coefficients	*P*	Shared variance (%)
(a) H/Ss ($N = 321$) (df = 316)			
PM	0·56	< 0·001*	31
WS	0·52	< 0·001*	27
TT	0·49	< 0·001*	24
CA	0·49	< 0·001*	24
SC	0·40	< 0·001*	16
BF	0·32	< 0·01	10
(b) AD/pts ($N = 49$) (df = 44)			
PM	0·57	< 0·001*	32
CA	0·57	< 0·001*	32
PT	0·54	< 0·001*	29
WS	0·47	< 0·001*	22
BF	0·38	< 0·01	14
SC	0·30	< 0·05	9

Key: see Table 9.

* Significant after Bonferroni's adjustment.

All the tests available for the H/Ss were taken from Spinnler & Tognoni's (1987) sample, and for only 49 out of 74 AD/pts. Partial correlations were calculated, partialling out the effect of age, education, and sex: nDCT is significantly correlated with all the tests taken into account. By and large, nDCT presents a similar correlation pattern in healthy and demented subjects, and the ranking shows a trend to display from more diffuse control abilities to more instrumental ones, the latter being chiefly the episodic learning and the visual recognition tests, and the former non-verbal intelligence (PM and WS). The high correlation with TT and CA is expected to some extent because of the known link between these functions and PM (Basso *et al.* 1981).

(ii) Psychometric evidence of the posterior-to-anterior evolution of AD-cortical encroachment

We checked the relationship between nDCT-scores and those earned by AD/pts on 2 sets of cognitive tests, namely tests held to be predominantly demanding on widespread and control abilities (PM and WS), and tests calling for more circumscribed, possibly retro-rolandic, abilities (TT, CA, BF and SC). The former set was expected to yield findings paralleling those of nDCT and the latter to a lesser extent. As BF and SC correlated less with nDCT than the other two tests (viz. TT, CA) of the second set, we focused our attention on them and on the control ability tests in order to get some psychometric information on the natural course of AD.

Given Nebes & Brady's (1989) negative findings regarding the AD/pts' breakdown of focused attention as well as our own data of 27% of AD/pts with a normal performance on Gottschaldt's Hidden Figures Test (Capitani *et al.* 1988), we would have expected an appreciable number of AD/pts to fall within the normal range of nDCT scores. Such an outcome would have helped us to find out whether performance on nDCT and other tests is incongruent. Given the assumption from PET-studies (review in Pawlik & Heiss, 1989; and Spinnler, 1991), that the AD-process encroaches earlier on the retro-rolandic cortical areas, what we in fact expected was that BF and SC (supposed to call for more circumscribed retro-rolandic abilities) would show a higher percentage of 'impaired' AD/pts than nDCT (supposed to call for more widespread abilities encompassing a crucial fronto-rostral aspect).

Two out of 74 AD/pts could not be tested on BF because of too severe aphasia, thus this assessment is based on 72 AD/pts. To compare the different tests, we decided to calculate the confidence limits of the frequency of pathological performances for each task. Two tasks can be considered to have different ranks of impairment if the respective confidence limits do not overlap. The 0·95 confidence limits of the proportions was evaluated through analysis of the likelihood profile (Aitkin *et al.* 1989) and the results are shown in Table 12.

Table 12. *Prevalence of pathological performance (i.e. equivalent score = 0) in patients with Alzheimer's disease*

	Prevalence of subjects with a pathological performance	%	CI of %s
nDCT	50/74	68	56–78
BF	42/72*	58	47–69
SC	23/74	31	21–42

* Two patients were not given the test.

The confidence limits of nDCT and BF proved to overlap widely, whereas the confidence limits of SC are completely separate from those of the two tests above. So our expectation that AD/pts performance on SC and BF would be more deranged than on nDCT was not borne out: on the contrary, AD/pts seem to perform worse both on nDCT and BF than on SC, even when allowance is made (as in all inter-test comparisons of this study) for scale and difficulty differences across tests (Capitani & Laiacona, 1988).

One comes to the same conclusion when a single-case analysis is carried out. Actually, out of 74 AD/pts, there are only two patients with a widely normal nDCT adjusted score (Equivalent Score 3 or 4) and a pathological adjusted score on the BF (Equivalent Score = 0), and none with a normal nDCT and a pathological SC, whereas the opposite dissociation is far more frequent: adopting the Equivalent Scores system, compared with only two patients scoring zero on nDCT and 3 or 4 on BF, there are fifteen

patients with pathological performance on nDCT and a normal adjusted score on SC.

(iii) Analysis of the errors of AD/pts, sH/Ss and F/pts

These data will be used to discuss the proposed sequence of actions involved by nDCT, which will be detailed in the Discussion.

Having raised the point on the way in which nDCT was carried out by AD/pts, we had to check the role of frankly unreliable behaviour, i.e. errors of commission. In order to investigate why AD/pts earned poor nDCT scores an analysis of errors was carried out. AD/pts' poor nDCT scores were mainly due to omissions which accounted for 90·2% of all errors within the time limit of 45 s. False alarms and perseverations account for the remaining 9·8% of errors within time limit (Table 13). When they occurred, they took the form of scattered wrong cancellations, or rarely of disinhibited go/no-go behaviour giving rise to clusters of false alarms (5·4% unforeseeable false alarms) and sometimes of perseverative errors (4·4%) from a previous matrix (viz. cancellation of digits that were targets in the previous matrix). Perseverations occurred almost only in the first 2 to 4 lines. As for the omissions, in line with Bruggman *et al.*'s (1989) findings on attention impaired patients, those due to the time-constraint accounted for 53% of the overall omissions, while lacunar omissions on the scanned line accounted for the remaining 47% (Table 14). Summing up, there is very little evidence that AD/pts' poor nDCT scores stem from commission errors, though it is apparent that they stem predominantly from omission errors.

Table 13. *Analysis of errors on nDCT: percentage out of total errors is reported. Patients with Alzheimer's disease and patients with frontal lobe lesions were given the task within time limit of* 45 *s, whereas 'stressed' healthy subjects had to perform the test in* 10 *s*

	Errors within time limit	FAs *N* (%)	P *N* (%)	O *N* (%)
AD/pts (*N* = 74)	1202	65 (5·4)	53 (4·4)	1084 (90·2)
F/pts (*N* = 26)	150	1 (0·7)	0 (0)	149 (99·3)
sH/Ss (*N* = 24)	107	6 (5·6)	0 (0)	101 (94·4)

Key: FAs = false alarms; P = perseverations; O = omissions.

Table 14. *Classification of omissions according to time constraint: percentage out of total omissions is reported. Patients with Alzheimer's disease and patients with frontal lobe lesions were given the task within time limit of* 45 *s, whereas 'stressed' healthy subjects had to perform the test in* 10 *s*

	Total omissions (*N*)	Within time limit *N* (%)	Out of time *N* (%)
AD/pts (*N* = 74)	2310	1084 (46·9)	1226 (53·1)
F/pts (*N* = 26)	400	149 (37·2)	251 (62·8)
sH/Ss (*N* = 24)	695	101 (14·5)	594 (85·5)

In Tables 13 and 14 error-data of F/pts and sH/Ss are set out with those of AD/pts. In all three experimental groups (i.e. AD/pts, F/pts, sH/Ss) a similar trend of the errors is at work (Table 13), with the marginal exception the perseverations observed only in the AD/pts group. In fact, omissions appear, in all three groups, to be by far the predominant type of error. However, in a face-value comparison both F/pts and sH/Ss performed nDCT with more 'out-of-time' *versus* 'lacunar' omissions with respect to AD/pts (Table 14). Whereas this outcome can be traced back to the narrower time-constraint allowed to sH/Ss, a slower and more accurate strategy of F/pts with respect to AD/pts was unforeseen. nDCT mean scores achieved by F/pts and sH/Ss are, respectively, 34·6 (S.D. 11·11) and 20·88 (S.D. 6·17).

One may note that these F/pts achieve a mean score that is close to that of H/Ss, and less than 20% of them performed below the cut-off; moreover sH/Ss are very close to the AD/pts achievement. These data will not be commented on further.

DISCUSSION

First, we will deal with general points bearing on the psychometric assessment of attentional resources in AD. In general, we need to bear in mind that a given cognitive task, when used in brain-damaged patients, provides measures that may no longer have the same psychological meaning that they have in H/Ss. Compensatory strategies in brain-damaged patients can be at

work, and it has been shown (Basso *et al.* 1985) that they may even change – while producing comparable scores – across subgroups of patients according to the locus of lesion and/or the predominant cognitive disorder (Basso *et al.* 1985). In a multi-component cognitive disorder such as AD, the psychological construct of a given test (usually multi-componential itself) needs to be reassessed. In the case of nDCT, this has been accomplished by comparing the same frame of inter-test correlations computed in H/Ss and in AD/pts. The general pattern that emerged in AD/pts is fairly akin to the one found in H/Ss, and the ranking of the test according to the product-moment coefficients in AD/pts more or less confirms the separation of values belonging to the most 'controlled' (e.g. Raven's matrices, highest correlation) *versus* those belonging to the most 'instrumental' (e.g. Street's Completion Test, smallest correlation) functions. Thus the notion that a classical cancellation test, such as nDCT, yields in AD/pts measures that can be assumed to be 'attentional' in nature to a rather similar degree as in H/Ss is acceptable.

Cancellation tests call for selective reaction to a pre-determined stimulus (i.e. the target), actively ignoring any other stimulus (i.e. the distracters). Any information to be ignored in nDCT (i.e. non-targets) is likely to follow an active mechanism (similar to the one at work in Stroop's (1935) test or to the Simon & Acosta (1982) effect) the features and attentional cost of which implies that cancellation tests have to be conceived as divided instead of focused attention tasks. We think that nDCT involves 3 sequentially arranged sets of action, namely: (i) assigning a special salience to the 2 or 3 (according to the matrix at study) digits predetermined as targets, this is likely to give rise to a privileged representation to be held in a buffer as long as the task runs (45 s); (ii) scanning the sequence of digits line by line from top to bottom (Fig. 1) and deciding what is a target and what is not as quickly as possible. The scanning sequence is suggested both verbally by formal instructions and by practising on the 1-digit target matrix. The quick-running strategy of letting the expected *Gestalt* emerge from a template scanning would possibly work only for the 1-digit target, a more featured analysis being likely whenever the search is for 2 or 3 spatially independent digits acting as targets in the same matrix. It is a perceptual decision that paces the scanning (gaze shifting) activity and, when a target is recognized, it triggers the cancelling action; (iii) pencilling out a target: this involves a motor act involving the mechanisms underlying stimulus reaching.

Following this processing sequence – trigger representation, perceptual decision while scanning, and cancellation – how are AD/pts likely to manage the steps, and where do they fail? To answer these questions we had no choice but to rely on the analysis of errors. It is only future research (e.g. achieving response-specific RT) that can provide goal-directed evidence on this issue.

(i) The number of false alarms (i.e. crossing out of a non-target digit) is very marginal; therefore the contribution from poor or evanescent grasp of the targets seems to be minor: after all, they are printed at the top of each matrix. Moreover, run-in lines of each matrix and practice on the 1-digit target matrix prevent misunderstanding of the task instructions, that are *per se* very easy to grasp. What is missing is a direct check on how the targets were encoded, whether by numerical reference or as visual patterns, or both, and whether this differs from H/Ss to AD/pts, and even from one patient to another.

(ii) Impairment of the second step, namely perceptual decision while scanning, seems to be the hallmark of the AD/pts' behaviour. At least three defective sub-components can be detected: (a) one is unsystematic within-line scanning in spite of the left-to-right reading procedure suggested by the examiner in the practising trials. Wild random scanning hardly ever occurred (see below). There were some patients who, when starting a new line, failed to take the next one in the top-down sequence, either skipping one or two lines below or jumping back to a line above already scanned. Use of a finger tip or pencil to aid scanning was never allowed; so the patient had to rely solely on a precise gaze shifting mechanism, that is stay in a non-aided visual searching setting; (b) the second subcomponent is the poor outcome of the trade-off between the gaze moving program and the perceptual decision between targets and non-targets. This gives rise to a passive scanning activity, 'looking without seeing', that is per-

ception does not trigger and pace either cancellation or gaze shifting; and (c) lastly, the slowness in making the discriminating decision. AD/pts do not appear to be able to use the quick, almost automatic, data-driven cancelling routine that healthy people appear to employ. This seems to be the main reason for the very frequent incomplete work-out of the test-matrices (overall 71% and 74% of AD/pts did not complete the task of, respectively, the 2- and 3-digits target matrix in the allotted 45 s for each). On the other hand, only 2% of AD/pts produced perseverative errors, which are known rather anecdotally to be part of the AD-behaviour (Sjögren *et al.* 1952).

(iii) As to the third step, failing to reach the target when pencilling it out does not seem to be a major error in any but 2 AD/pts entering this survey. Pencil strokes of these 2 AD/pts were so wildly placed between targets and even dispersed outside the frame of the matrix that they were considered to suffer from reaching disorders, such as those framed in the Balint–Holmes syndrome; concomitant clinical information confirmed this suspicion.

Hence we contend that the poor nDCT scores of AD/pts are mainly due to 'passive scanning' and slowness in the perceptual decision, as purely scanning or reaching defects were very rarely a prevailing cause of poor performance. This conclusion is somewhat at variance with Hutton *et al.*'s (1984) findings, which point to defective scanning as a pervading visuo-perceptual disorder in AD/pts.

On the evidence of our error analysis, the chief cognitive deficiency underlying the poor performance of AD/pts on nDCT can be explained in terms of failure of the attentional component (points (b) and (c) of the second step). The failure to deploy attentional resources effectively between the scanning programme (with its systematic requirement) and perception (with its target/non-target decision requirement) suggests that the resources are actually insufficient. This gives rise to a break of the scanning/decision trade-off.

When healthy people are asked to speed up their performance on the 2- and 3-target matrices within a 10 s time limit per matrix instead of 45 s, they commit errors like those of AD/pts in the formal experimental setting, namely omissions.

Patients with frontal lobe lesions (45 s allotted) made similar errors: mainly omissions and, unexpectedly, very few perseverations. Moreover, frontal patients were accurate (false alarms accounted for only 0·7% of all errors), but quite slow, as their errors were mainly due to lack of time (omissions out of time accounted for 62·8% of the total omissions), even when confronted with AD/pts performance (see Table 14). Given the impulsiveness of these patients, well known from the anecdotal literature, this finding was not what we had foreseen, even if it is in keeping with Kleist's 1934 *Antriebsmangel* hallmarking most F/pts. F/pts' findings on selective attention need to be much more detailed than they are, and nDCT data on F/pts are of course in need of replication. Over and above they point to a conservative coping strategy in the frame of the speed/accuracy trade-off paradigm, as if a compensatory strategy would be adopted to overcome the postulated reduction of attentive resources of patients bereft of their pre-frontal neuronal devices.

The similar error profile in the three experimental groups considered (AD/pts, F/pts and the sH/Ss), points toward the use of a common strategy to solve the task. This indicates that any resource-limiting condition, either due to pathology or to experimental setting, produces the same outcome. One could cast some doubts on the importance lent to the prevalence of omission errors in determining nDCT poor scores, suspecting that there is a test-bias favouring the probability of omissions. Whereas this is likely to be true for 'out of time' omissions, we are confident that 'lacunar' omissions have the same *a priori* likelihood to be made as any other type of error.

We feel that the key shortcoming in AD/pts is a limitation on the ability to switch of a semiautomatic scanning habit whenever they have to identify a target, this being the hardest subcomponent involved in the test. The ability to switch off would fit neatly into the Supervisory Attentional System of Norman & Shallice (1980, 1986). This view is plausible considering that increasingly noisier and flawed devices (such as the associative cortical devices involved in handling instrumental performances of a brain already encroached upon by the AD process) call *per se* for more intensive attentional control,

severely curtailing the healthy domain of automatic activities (Spinnler, 1991).

Given the reasonable claim that nDCT has, in AD/pts as in H/Ss, a predominant attentional load, and that poor economy of attention resources and allocation is likely to be the most important factor in the cancellation impairment of AD/pts, the results on the search for psychometric evidence of the posterior-to-anterior spread of the degenerative process of AD pointed out by PET-studies (Pawlik & Heiss, 1989), deserves a comment. Quite a number (24%) of our AD/pts show little or no impairment on nDCT. This proportion of psychometrically nDCT unimpaired AD/pts ties in with one supplied by another selective attention test in the visual domain, namely Gottschaldt's Hidden Figure Test, in which 27% of AD/pts, comparable to those involved in the present survey, were unimpaired (Capitani *et al.* 1988). Given these figures of not (or rather not yet) impaired AD/pts, there have been hints that psychometric data could be used to mirror the metabolic posterior-to-anterior evolution data (Pawlik *et al.* 1989) of the AD-encroachment on the cortex. Our findings fail to provide purely psychometric support for the posterior-to-anterior evolution of AD. This failure may well be due to a test-flaw. This expectation, in fact, holds good only if the attentional component of our test could be conceived as an ability linked to the rostral portions of the brain (Perecman, 1987; Shallice *et al.* 1989; Hiltbrunner *et al.* 1990). Oddly enough, only 5 (19%) out of a group of 26 CT – assessed non-demented frontally damaged adult patients (2 out of 12 with a unilateral left lesion, none of the 8 with a unilateral right lesion, and 3 out of 6 with a bilateral lesion) in a chronic state of the disease, fared badly on nDCT: a finding that is not in line with the exclusive rôle of pre-frontal areas in selective attention tasks.

Alternatively, one might resort to a general speculation undermining a traditional neuropsychological criterion in the context of cognitive studies in AD/patients. Given the pervading cognitive and neurostructural impairment in AD, double dissociation could hardly be proof of a relationship between damage/sparing of nervous devices and impairment/unimpairment of test performances. Functional breakdown thresholds need not be equivalent across different structures. It might well be that a given metabolic drop in one region leaves sufficient resources to cope with a test performance, whereas a comparable drop in another region prevents coping with another performance. At present, nobody has any idea of the regional metabolic requirements of test-performances. Hence, psychometric paralleling of PET-findings in AD was inherently a risky venture. It remains likely that both psychological tests and neuro-imaging techniques are still inherently risky methods of assessing underlying pathological processes.

A few other findings of this study deserve a comment.

Sex is a relevant factor in nDCT: healthy females are significantly less efficient than healthy males (37·57, S.D. 9·02 *versus* 41·37, S.D. 8·53, respectively). It is worth noting that in Spinnler & Tognoni's (1987) test-standardization, the other tests where sex played a significant rôle were visuo-spatial span, visuo-spatial supraspan learning, primary effect in free recall, Elithorn's perceptual maze, males doing better than females in all cases. For nDCT it is possibly the spatial component which works against healthy women, a trait common to the other tests which revealed the same difference (with the exception of the primacy effect in the verbal free recall task). This in fact makes sense in the sex-linked cognitive hemisphere asymmetries hitherto described in H/Ss (McGlone, 1986; Bradshaw, 1989).

The poor sensitivity of nDCT to the cognitive worsening of AD/pts may have a strictly psychometric explanation, namely the rather poor test/retest reliability of nDCT, in H/Ss (0·53) and the wide dispersion of the scores in the pathological sample (19·98, S.D. 10·94). More important, perhaps, the lack of significant impairment over time may be due to the short interval (about 6 months) between the 2 assessments, a finding similar to one turned out in a longitudinal study of AD/pts on ideo-motor apraxia (Della Sala *et al.* 1987). In fact, of the 6 tests considered, only the overall worsening trend of Token Test reaches significance.

The forecast of increasing difficulty of the test, going from the 1-digit target to the 2- and 3-digit target, follows the assumption that pencilling out an increasing number of different targets (respectively, one, two or three) transforms a

simple focus shifting task, when one target has to be detected against the noise of all non-targets in the first matrix, into a task where focusing attention has to be distributed across more than one target at the same time. Whereas there is a statistical difference between the 1-target digit matrix and the 2- and 3-target digit matrices, there is no such significant difference between the latter two. This finding possibly points to a qualitative searching difference, namely a template, emerging, search when the subject is faced with 1 target, *versus* an exhaustive feature analysis procedure when there is more than one target. In other words, the poor discriminative power of the 1-target matrix ties in with the relatively preserved focused attention capability of mildly impaired AD/pts, already pointed out by Nebes & Brady (1989). The increase of discrimination attained by the 2- and 3-digit matrices suggests a radical change in quality of the attentional demand involved, namely, of dividing attentional resources. Resources have in fact to be divided twice, namely between actions (viz. scanning and target/non-target decision) and between targets (two or three) to be held in a working buffer. Both divided attention performances are well-known to be severely impaired in AD/pts (Baddeley *et al.* 1986; Nebes & Brady, 1989). So, we maintain that the selective attentional load of nDCT is of the divided rather than of the focused type.

As a general remark, we maintain that one ought to be extremely careful, when dealing with AD test-assessments. First, it is necessary to try to clarify what cognitive function or action it is believed to be primarily tested, making every effort to explain what processing subcomponents are suspected to be involved therein. Secondly, we have often only too vague opinions on what nervous structures are critically involved in a given test-performance. Here again, at the present state of knowledge, it might be useful to distinguish the 'instrumental' and 'control' set of components (Spinnler, 1991), and provisionally to attach them to the retro-rolandic and limbic or pre-frontal cortical devices, respectively. Third 'Attention' – when it is the psychological domain of research on AD/pts as in our case – is protean as a concept (from James, 1890, and Pillsbury, 1908, to Reason 1984, and Shallice *et al.* 1989), just as AD itself, from a neuropsychological perspective, is protean as a disease (Capitani *et al.* 1986; Martin *et al.* 1986; Spinnler & Della Sala, 1988; Baddeley *et al.* 1991). This implies the need to detail as precisely as possible the psychological model of reference (Baddeley, 1986; Normal & Shallice, 1986; Reason, 1984), foreseeing that the need of further fractionation (Della Sala *et al.* 1992; Della Sala, Laiacona, Spinnler, Trivelli, submitted) is very likely. With respect to AD, a neuropsychological model is unfortunately lacking or only in the early stages (Jorm, 1986; Spinnler, 1991). Finally, there is the tacit agreement that all adult brains – independently of the cognitive life-history of their owners and their ages – process information according to an identical hierarchy of functions whether they are healthy or damaged. Destructuring after brain damage is generally held to follow an identical sequence in all patients (from Jackson, 1968, to Bernstein, translated 1967, and Luria, 1980; see review in Goldberg & Bilder, 1987). This agreement is much more a matter of convention than an experimentally backed claim, particularly when a chronically progressive disease such as AD is concerned.

Given such a complex net of uncontrolled interactions at a strict psychological as well as at a neuropsychological level, we forecast that the future lies with biological approaches to AD – particularly by means of regional PET-assessments of the cerebral metabolism and the use of neurotransmitters, or even the regional phosphor spectroscopy by means of NMR (Pettegrew, 1989) – which should begin to put neuropsychological research of dementia on firmer bases than the strictly descriptive ones presently available. Presently, the inter-relationship of the steps making up a definite psychological reference-model of the processing involved by testing tools, of the subserving neuronal devices and of the nosographical fractionation of the progressive cortical degenerations has to be clearly set forth (even if only on a predominantly speculative basis), in order to make explicit and verify a neuropsychological hypothesis. An example of an experimental pitfall due to the reasons above is deliberately reported above under heading (ii) of the Results.

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