The fractionation of remote memory
Evidence from a longitudinal study of dementia of Alzheimer type

John D. W. Greene and John R. Hodges

**Summary**

We studied remote memory, both autobiographical and public, longitudinally over a 1-year period in 24 patients with dementia of Alzheimer type (DAT) and 30 matched controls. Although both public and autobiographical memory were impaired in DAT, public memory deteriorated longitudinally, while autobiographical memory did not. These data support the hypothesis that remote memory may be fractionated and that one important dichotomy is autobiographical memory versus famous person knowledge. A cognitive analysis of famous face and name processing showed evidence of progressive breakdown in the identification of famous faces and names, with preservation of face and name recognition, and face naming. The declining performance on identification appeared to be due primarily to loss of semantic knowledge regarding famous persons, while a retrieval deficit contributed more significantly to the proper name anomia which was over and above the semantic deficit in DAT.

**Keywords:** Alzheimer's disease; remote memory; semantic memory; autobiographical memory

**Abbreviations:** AMI = Autobiographical Memory Interview; DAT = dementia of Alzheimer type; MMSE = Mini-Mental State Examination

**Introduction**

One of the major developments in neuropsychology has been the appreciation that memory is not a unitary cognitive measure, but comprises several subcomponents, viz. explicit and implicit, short-term and long-term, episodic and semantic memory (Tulving, 1983, 1987; Baddeley, 1988; Squire et al., 1990). Neuropsychological studies on brain injured patients have shown that these subcomponents may be separately affected by cerebral insult. It is also well known that within the field of episodic memory, anterograde and remote memory may dissociate: extensive anterograde amnesia with limited retrograde amnesia has been well described (Squire et al., 1975, 1976; Cohen and Squire, 1981; Speedie and Heilman, 1982; Winocur et al., 1984; Zola-Morgan et al., 1986). As reviewed by Kapur (1993), organic pathology may less commonly produce retrograde amnesia with minimal anterograde impairment (Goldberg et al., 1981; Kapur et al., 1989, 1992; O'Connor et al., 1992; Markowitsch et al., 1993).

Previous studies of remote memory have tended to address the status of remote memory in general, and the attendant issue of a temporal gradient, rather than on individual subcomponents of remote memory (Sanders and Warrington, 1971; Seltzer and Benson, 1974; Albert et al., 1979; Meudell et al., 1980; Cohen and Squire, 1981; Zola-Morgan et al., 1983; Beatty et al., 1988; Sagar et al., 1988; Kopelman, 1989). Much less attention has been given to the possible fractionation of remote memory, although there have been several case studies showing deficits restricted to public figures or events (De Renzi et al., 1987; Ellis et al., 1989; Evans et al., 1995), or to autobiographical memory (Stuss and Guzman, 1988; Dalla Barba et al., 1990; Hodges and McCarthy, 1993).

Within the domain of autobiographical memory, a subdivision has been proposed between memory for personal semantics and incidents (Kapelman et al., 1989). In support of this proposal, relatively selective deficits of either incident memory (Dalla Barba et al., 1990; McCarthy and Warrington, 1992; Hodges and McCarthy, 1993) or personal semantic memory (Warrington, 1975; De Renzi et al., 1987; Hodges et al., 1992a) have also been described.
These findings raise theoretical issues regarding the nature of autobiographical memory (Hodges and McCarthy, 1995). It has been suggested that autobiographical memory has a different representation and/or organization than memory for public events (Baddeley, 1992). Retrieval and remembering autobiographical memories are thought to involve a complex, distributed system which requires problem solving, cross checking, verification and inference (Conway, 1987; Baddeley, 1992). Loss of autobiographical memory may be due either to disruption of so-called thematic retrieval frameworks or a loss of individual memory traces, as can occur in damage to fairly widely distributed temporo-parietal cortices (Kapur et al., 1992; Kapur, 1993; Markowitsch et al., 1993). For general semantic knowledge, the left temporal neocortex is felt to play a critical role (Patterson and Hodges, 1995). The issue of whether knowledge about famous people is represented in areas closely related to those specialized for face recognition—the infero-medial right temporal lobe—remains controversial, but all three cases so far reported with loss of person-specific semantic knowledge have had right temporal lobe pathology (Ellis et al., 1989; Hanley et al., 1989; Evans et al., 1995).

In DAT, it is known that memory is almost invariably the first component of cognition to become impaired. Although the anterograde episodic memory impairment in DAT has been well characterized, the remote memory impairment has been less extensively addressed (for review, see Hodges, 1995). We will now briefly discuss previous studies of remote memory in DAT, firstly those of memory for public figures and events, and then those addressing autobiographical memory.

Studies involving famous faces (Wilson et al., 1981; Beatty et al., 1988; Hodges et al., 1993; Greene and Hodges, 1995) and famous events (Sagar et al., 1988; Kopelman, 1989) have all shown remote memory impairment in DAT. Although Wilson et al. (1981) did not find a temporal gradient in the pattern of remote memory impairment, the other three studies did. Hodges et al. (1993) borrowed techniques from cognitive neuropsychology to address the nature of the remote memory impairment seen in DAT. They took the information-processing model of face identification proposed by Bruce and Young (1986) and amended by Valentine et al. (1991) to include name processing. In this model, face and name recognition and identification, and face naming, involve a sequence of discrete cognitive processes. First, structural encoding of the perceptual features provides a visual description of the seen face. Recognition of the face as familiar proceeds by comparing this with the store of known familiar faces (or face recognition units). An identical and parallel procedure is postulated for name recognition. The next stage consists of accessing person-specific semantic knowledge. Naming requires the additional activation of phonological name codes. Patients may show breakdown at any level and the failure to name a picture of a famous person or to recognize a famous name may, therefore, reflect an impairment at any level of this process.

It should be mentioned that these serial models have been modified to an interactive activation and competition architecture model for face and name recognition (Burton et al., 1990; Bruce et al., 1992; Burton and Bruce, 1993) and naming of faces (Burton and Bruce, 1992) which share in common with more traditional models the principle that naming occurs only if semantic information is present. They differ, however, in the proposal that names are no different to other unique semantic information.

Hodges et al. (1993) analysed recognition of famous faces from amongst non-famous foils, identification (i.e. the ability to provide specific information about unnamed faces) and naming, with and without semantic and phonological (first name) cues. Their DAT group was impaired on all components, but showed relative preservation of recognition, and naming with first name cues. They argued that the impairment was due primarily to loss of person-specific semantic knowledge and that pre- and post-semantic processes remain relatively spared in DAT. Subsequently, Greene and Hodges (1995) extended their study to include name as well as face processing. A cognitive analysis revealed that, although there was evidence of impairment at all levels, the bulk of the damage occurred at the semantic level of processing with relative sparing of the pre- and post-semantic stages of recognition and name production. There was strong support for the hypothesis that faces and names of famous people draw on the same pool of semantic information. There was a limited association between face and name recognition, suggesting that, although separate, these processes do have a degree of association. Remote memory was found to be dissociable from anterograde memory, and to have poor association with general semantic memory.

Autobiographical memory, despite its obvious everyday importance, has been investigated relatively little in DAT, perhaps due to the unavailability, until recently, of suitable instruments. Sagar et al. (1988) gave the cued autobiographical test (modified from Crovitz and Schiffman, 1974) and showed impaired autobiographical memory, with a shift in the pattern of responses to more distant time periods. Kopelman (1989) found that both the personal semantic and episodic components of autobiographical memory were impaired, with a modest temporal gradient. Impaired autobiographical memory was also noted by Dall’Ora et al. (1989), although they did not find a temporal gradient. In a more recent study (Greene et al., 1995), we confirmed that autobiographical memory was impaired in DAT, even in patients with minimal disease, and that there was evidence of a very mild temporal gradient on only one of four measures; personal incident memory on the Autobiographical Memory Interview (AMI). There was, therefore, some support for the fractionation of autobiographical memory into personal semantic and incident components.

The major limitation of all of the above studies of remote memory relates to their cross-sectional design. Although such methods are adequate for testing anterograde episodic memory, where the examiner can control and verify the
presentation of material to be learned, there are significant drawbacks in studies of remote memory. In studies involving famous people (or events), failure to identify or name the target famous figure may represent a loss of knowledge of the famous person; alternatively, the subject may never have known the identity of the famous person in the first place. Differences in education and attention paid to current affairs lead to subjects having widely varying databases regarding public figures and events. For instance, a DAT patient's inability to recognize, identify and name Groucho Marx may be due to loss of semantic knowledge of him. Alternatively, the subject may have never watched much television or gone to the cinema, and may never have known who Groucho Marx was. Attempts to match patients and controls on the basis of age, education and baseline IQ may not deal totally with this problem.

A further problem with studies of autobiographical memory relates to checking the veracity of subjects' responses, which may be confabulations. This can be controlled for, either by retesting the patients after an interval, or by verifying the results with family members, both of which are time-consuming and not entirely reliable. Another complicating factor is that some people have intrinsically less eventful lives, and this may result in poorer performance on autobiographical tests.

In longitudinal studies, patients act as their own controls, which allows one to circumvent many of these drawbacks. This is particularly advantageous when trying to determine the nature of the cognitive deficit underlying remote memory impairment. For instance, if a patient can identify Groucho Marx at year 1, then we know that he forms part of the subject's database regarding famous people. Failure to do so a year later may be due to a loss of storage of semantic knowledge regarding Groucho Marx, or alternatively due to an inability to retrieve this information. Retrieval deficits would also, however, be as likely to lead to misidentification at year 1 and correct identification at year 2. By adjusting for this, we hope to study how much any apparent deterioration in identification longitudinally may be occurring as a result of loss of semantic knowledge storage, and how much might be due to retrieval deficits. This is of theoretical importance given the debate regarding whether the general semantic impairment seen in DAT is primarily one of loss of storage, or lack of access due to a retrieval deficit. Although the bulk of investigators favour the former explanation (Martin and Fedio, 1983; Chertkow and Bub, 1990; Chertkow et al., 1992; Hodges et al., 1992b; Chan et al., 1993), others favour an access deficit (Nebes, 1989; Bayles et al., 1991).

To the best of our knowledge, there have been no reported longitudinal studies of remote memory in DAT. Our study was undertaken to examine the relationship between remote memory for public figures and autobiographical memory in a group of patients with early DAT. The finding of decline in only one putative subcomponent of remote memory would be a powerful argument for the proposed fractionation of remote memory.

Aims
We wished to address the following questions. (i) Is there evidence of deterioration of remote memory over 1 year in DAT patients, as measured by both autobiographical memory and person-specific memory for famous people? (ii) Within the realm of remote memory, is there any support for the proposed fractionation between autobiographical memory and memory for famous people? (iii) If there is a deterioration in public memory, which aspects of face and name processing appear responsible? (iv) If there is decline in ability to identify and name famous people, is this due to a loss of storage of semantic information, or due to a failure of access?

Methods
Subject group
Two groups consisting of a total of 54 subjects participated in the study: 24 patients with DAT (15 females and nine males) and 30 neurologically intact normal control subjects (15 females and 15 males). Written informed consent was obtained from all subjects or the care-givers, where appropriate.

Initially, 33 DAT subjects were chosen from ~50 patients undergoing prospective evaluation at the University of Cambridge Neurology unit who were willing to be enrolled into a longitudinal study of remote memory and related cognitive deficits in DAT. All 33 were tested at entry to the study (year 1). Twelve months later, 24 patients were available for re-testing (year 2). Drop-outs arose from some patients refusing further testing, inability to comply with testing, and the development of a cerebrovascular accident in one. It should be noted that the subgroup of 24 patients who were retested did not differ significantly from the nine patients who were tested only at year 1, for age, education, premorbid IQ or dementia severity as measured by the Mini-Mental State Examination (MMSE). The diagnosis of probable DAT was made by a neurologist according to the criteria developed by the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association, which consist of inclusion and exclusion criteria (McKhann et al., 1984). All patients presented with a 1–4 year history (confirmed by the care-giver) of progressive cognitive impairment predominantly affecting memory. All achieved a score of ≥4 on the Hachinski Scale (Hachinski et al., 1975), thus reducing the likelihood of multi-infarct dementia. Patients with a past history of known or suspected transient cerebral ischaemic event or stroke, alcoholism, head injury or major medical illnesses (e.g. cancer, anaemia, thyroid dysfunction, etc.) were excluded, as were those with past or current major (DSM III-R) depression. All patients were examined by a neurologist and a psychiatrist before entry into the study and underwent CT or MRI scanning together with the usual battery of screening blood tests to exclude treatable causes of dementia. All of the probable DAT patients were living
Table 1 Mean (SD) age, education and MMSE scores for the DAT cases and normal control subjects

<table>
<thead>
<tr>
<th></th>
<th>Controls (n = 30)</th>
<th>DAT patients (n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>67.9 (8.7)</td>
<td>69.8 (8.6)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>11.0 (2.9)</td>
<td>11.3 (3.1)</td>
</tr>
<tr>
<td>IQ (NART)</td>
<td>111 (17.7)</td>
<td>109 (13.4)</td>
</tr>
<tr>
<td>MMSE: score</td>
<td>29.5 (0.7)</td>
<td>23.9 (3.0)</td>
</tr>
<tr>
<td>range</td>
<td>(26–30)</td>
<td>(17–30)</td>
</tr>
<tr>
<td>Logical memory—immediate</td>
<td>19.8 (5.6)</td>
<td>8.3 (4.4)*</td>
</tr>
<tr>
<td>Logical memory—delayed</td>
<td>17.6 (6.0)</td>
<td>2.3 (3.4)*</td>
</tr>
<tr>
<td>Category fluency</td>
<td>112 (23.6)</td>
<td>64.2 (20.5)*</td>
</tr>
</tbody>
</table>

NART = National Adult Reading Test. *P < 0.0001.

with caregivers without institutional support. To further exclude cases with a dubious diagnosis, all patients have been followed-up for at least 12 months. Any patient showing improvement in cognitive performance over this period was excluded from the DAT cohort.

Normal control subjects were either spouses of patients or in-patients with non-cerebral pathology. Subjects with a history of alcoholism, drug abuse, learning disability, neurological or psychiatric illness were excluded. They were matched with the DAT patients on the basis of age and education level. All patients and controls were able to complete the entire battery. Subjects with clinically apparent visual and/or hearing impairments likely to affect their performance were excluded.

None of the DAT subjects, even the most impaired, could be considered severely demented, e.g. no patient was institutionalized or scored greater than grade 2 (moderate) on the Clinical Dementia Rating Scale (Berg, 1988). The numbers of subjects in each group and their mean ages, years of education and MMSE scores, are shown in Table 1, along with values for the same dimensions for the control group. The groups were well matched. Unpaired comparisons revealed no significant difference for age [t(61) = 0.89, P > 0.05], education [t(61) = -0.67, P > 0.05] or pre-morbid IQ as assessed by the National Adult Reading Test (Nelson and Willison, 1991) [t(61) = 0.50, P > 0.05]. Although both controls and DAT patients were above average for premorbid IQ, the means for these groups fall within 1 SD of normal.

It should be noted that many of our DAT patients with minimal disease obtained MMSE scores of 24 and above, which has previously been taken to be the lower limit of normal. It can be seen that our DAT group was, however, greatly impaired on memory measures such as logical memory and category fluency, consistent with a diagnosis of DAT.

Neuropsychological tests

This study comprised part of a wider investigation of explicit memory in DAT, including anterograde episodic memory (Greene et al., 1996) and executive function (Greene et al., 1995). Our previous cross-sectional studies have addressed remote memory for public figures (Greene and Hodges, 1995) and autobiographical memory (Greene et al., 1995), but we have not previously compared remote public and autobiographical memory, or reported longitudinal data.

Tests of autobiographical memory

Autobiographical memory interview (Kopelman et al., 1990). This test, developed by Kopelman et al. (1990) assesses personal semantic and autobiographical incident memory across three time periods: childhood, early adulthood, recent life. For each time period, the subject is asked to give personal semantic information (e.g. address of primary school) and autobiographical incident information (e.g. a particular incident occurring in childhood).

Some of the questions in the original test for the most recent time period referred to recent hospital attendances and are likely to be assessing anterograde memory rather than recent remote memory. We therefore modified the questions for the late adulthood time period to try to assess memory for events occurring before the onset of the pathology (e.g. an incident occurring on holiday prior to onset of memory problems).

Autobiographical fluency (Dritschel et al., 1992). In this fluency test, subjects are required to produce as many exemplars as possible in 90 s for each of the following six categories: names and incidents each for childhood, early adulthood and late adulthood. For names, the subject has to produce as many names of people met in the particular time period. No detail is required regarding the names. For incidents, the subject is required to produce as many unique incidents as possible in the time given. As soon as the tester is satisfied that the subject is describing a unique incident, the subject is asked to move on to another example.

Previous tests of autobiographical memory have led to ceiling effects in controls (Kopelman et al., 1990). The use of a fluency-based test avoids this ceiling effect. The problem of confounding recent remote memory with anterograde memory cannot be wholly avoided. However, recent remote memory was arbitrarily defined as referring to that part of the patient’s life over the age of 40 years.

The above two tests draw on the same core of autobiographical knowledge. The AMI is more structured, and provides specific contextual cues.

Tests of memory for famous people

Famous faces test. We used a modified and updated version of the famous faces test described by Hodges and Ward (1989). Fifty target photographs of prominent public figures were selected. An effort was made to select faces of people who had remained famous for a limited period, preferably a single decade between the 1940s and 1980s. There were 10 photographs from each of the five decades.
The photographs included politicians and statesmen, stage, film and TV personalities, and sportsmen. Black and white portrait photographs were used. A full list of the famous persons used in the test is given in the Appendix.

For each target photograph, three non-famous photographs were selected as foils. These were of the same age and sex, and from the same era as the target. The photographs of non-famous persons were selected from a wide variety of sources including year books, old magazines and newspapers.

For administration purposes, each target photograph was presented in a 2×2 array with its three matched foils. The position of the target was randomized with an overall balanced design. The test therefore consisted of 50 individually presented arrays. The order of the target photographs was arranged so that each block of five contained a photograph from each decade.

In our previous study (Greene and Hodges, 1995), we had tested naming before identification. We made the assumption that if naming was correct, then identification would necessarily be correct. Although we believe that this is highly likely to be the case, proponents of naming without semantics (Kremin, 1986; Shuren et al., 1993; Kremin et al., 1994) might argue otherwise. We therefore tested identification in all cases. For each photograph there were three potential parts to the test: recognition, identification and naming.

For recognition, subjects were presented with each array of four photographs and given the following instruction. ‘Only one of these four photographs is of a famous person. Can you point to the one you think is the famous person?’ If incorrect, the target photograph was pointed out to the subject.

For identification, subjects were then encouraged to provide a detailed description of the famous person represented. No clues were provided but the examiner probed for further details to obtain the subject’s most specific description using standard probes. For instance, in response to ‘a politician’ the examiner asked what position did he/she hold and what party did they represent. For ‘actor or actress’ subjects were asked what film or TV series they appeared in, etc. Responses scored as correct contained specific identifying information (e.g. Glenda Jackson, ‘She’s the actress who’s now a Labour MP’; John Profumo, ‘He’s the Tory Minister who had the sex scandal’). Incorrect responses were generic or vague non-identifying statements (e.g. ‘a famous film star’; ‘the foreign politician’, etc.). The subjects were probed until the examiner was convinced that the subject had provided sufficient unique identifying information regarding the famous face, or until it appeared that the subject could only provide vague identifying information or none at all. If the subject produced sufficient information to uniquely identify the famous face, then one mark was given. Any less information was given no marks.

For naming, subjects were then asked to name the famous person represented. Only a correct full name (i.e. first and last names) was accepted.

Scores were thereby obtained for the overall total correct and for the items for each decade in each of the three test conditions as follows: (i) recognition, the number correctly recognized as famous (chance level 25%, i.e. 12.5/50); (ii) identification, the number of items correct producing specific identifying information (possible scores for each item were 0 and 1); (iii) naming, the number correctly named without cues (possible scores were 0 and 1).

**Famous Names Test.** On a separate occasion from the administration of the Famous Faces Test, we administered a famous names test. The same fifty famous people were used in this test. However, instead of being shown photographs, the subjects were shown cards with four names, one being famous with three foils.

For administration purposes, each target name was presented with three matched foils. The position of the target was randomized with an overall balanced design. The test therefore consisted of 50 individually presented arrays. The order of the target photographs was arranged so that each block of five contained a name from each decade.

For each name there were two potential parts to the test: recognition and identification.

For recognition, subjects were presented with each array of four names and given the following instruction. ‘Only one of these four names is of a famous person. Can you point to the one you think is the famous person?’ If incorrect, the target name was pointed out to the subject.

For identification, subjects were encouraged to provide a detailed description of the famous person represented. No clues were provided but the examiner probed for further details to obtain the subject’s most specific description using standard probes, as in the famous faces test.

Scores were thereby obtained for the overall total correct and for the items for each decade in each of the two test conditions as follows: (i) recognition, the number correctly recognized as famous (chance level 25%, i.e. 12.5/50); (ii) identification, the number whose identity was correctly established.

Our use of the same 50 famous persons for both the faces and the names tests allowed us to examine each of the subcomponents of face and name processing, i.e. face and name recognition units, semantic knowledge (which might be common for faces and names, or separate) and the post-semantic lexicon.

The same subjects were followed up 1 year later, when the famous faces and famous names tests were repeated. For each patient, and for each face, longitudinal performance could be determined on each of the following measures: face recognition, face identification, face naming, name recognition and name identification.

**Statistical analysis**

StatView (Abacus, 1992) and Statistical Packages for Social Sciences (SPSS, 1994) statistical packages were used. For analysis of the cross-sectional data for the autobiographical and public memory tests, inter-group differences between
DAT patients and controls were tested using unpaired comparisons. Performance on these tests longitudinally was studied by repeated measures ANOVA. If this showed a group by condition interaction, then post hoc analysis using Student–Newman–Keuls test was used.

To study the relationship between public and autobiographical memory within remote memory, a correlational analysis was performed. On account of the number of comparisons, only those correlations with a $P$-value $< 0.01$ were considered significant.

The issue of the relationship between public and autobiographical memory was further addressed by entering public and autobiographical test results into a principal components factor analysis. Only those factors with eigenvalues $> 1$ were retained. The variance proportion shown is an estimate of the proportion of variance that the eigenvalue and its eigenvector account for when they are used to define a factor. The final communalty estimate shown represents the total proportion of variance of the variable that can be predicted by the factors. An oblique solution was determined using the orthonormal solution with varimax rotation.

Longitudinal performance on remote memory was assessed for each subject. For each famous face, it was possible to study performance with time for each of the following measures: face recognition, face identification, face naming, name recognition and name identification. For example, for face recognition of a particular face, the subject’s performance at year 1 and year 2 were determined. Fifty items for each of 24 patients yielded 1200 subject-faces. This enabled us to study item-by-item correspondence on tests of subcomponents of public memory.

We were interested in comparing the longitudinal deterioration in public and autobiographical memory. To obtain a measure of autobiographical memory, the personal semantic and incident components of the AMI were expressed in terms of controls’ performance, i.e. Z-scores. These two Z-scores were then averaged to provide a measure of autobiographical memory. This was done for years 1 and 2. Similarly, for public memory, famous face and famous name identification Z-scores were derived, and these were averaged to give a measure of public memory. By this means, we were able to study the deterioration in autobiographical and public memory over 1 year in DAT patients in terms of control group SD units.

**Results**

**Cross-sectional study of memory for famous people and autobiographical memory**

Our cross-sectional data comparing DAT patients and controls have been published elsewhere (Greene and Hodges, 1995; Greene et al., 1995) and will be discussed only briefly. For memory for public figures, we found that all components of the faces (recognition, identification, naming) and names (recognition, identification) tests were impaired in DAT patients (see Table 2). To study which component of face processing was most impaired, a repeated measures ANOVA showed effects of group (DAT versus controls) [$F(1,52) = 41.3$, $P < 0.0001$] and condition (recognition, identification, naming) [$F(2,104) = 346$, $P < 0.0001$] and a group by condition interaction [$F(2,104) = 48.5$, $P < 0.0001$]. Post hoc comparisons showed that this was due to the fact that the DAT patients were disproportionately impaired on the face identification component. Similarly, for famous name processing, repeated measures ANOVA showed group (DAT versus controls) [$F(1,52) = 35.3$, $P < 0.0001$] and condition (recognition, identification) effects [$F(1,52) = 96.4$], but also a group by condition interaction [$F(1,52) = 64.8$, $P < 0.0001$]. Post hoc comparisons showed that DAT patients again showed disproportionate impairment on the identification task. For autobiographical memory, DAT patients were significantly impaired with respect to controls, on both the AMI and autobiographical fluency tests (see Table 2).

To study the issue of the fractionation of remote memory, results of our tests of public and autobiographical memory were entered into a correlation analysis (see Table 3). It can be seen that there were no significant correlations between any of the tests of public memory and any of the autobiographical memory tests. This suggests that public and autobiographical memory are indeed separate subdivisions within remote memory.

An alternative means of addressing this issue is to enter the tests of public and autobiographical memory into a principal components analysis. As performance on face recognition influences identification and subsequent naming, only face identification was entered into the factor analysis. Similarly, only the identification component of the famous names test was entered. For autobiographical memory, only data from the AMI were entered, as this is an established and well-validated test.

As can be seen from Table 4, two separate factors emerged. The first factor comprised famous face and famous name identification, and seems to represent knowledge regarding famous persons, whether accessed by faces or names. The second factor, the personal semantic and incident components of the AMI, represents autobiographical memory. This again argues that the subdivision of remote into public and autobiographical memory is indeed relevant.

**Longitudinal study of memory for famous people and autobiographical memory**

**Cognitive analysis of public memory**

To study the impact of disease progression on subcomponents of face processing, we performed a two (groups: DAT year 1 versus DAT year 2) by three (conditions: recognition, identification, naming) ANOVA which indicated a non-significant effect of group [$F(1,46) = 0.1$, $P > 0.05$], a significant effect of condition [$F(2,92) = 379$, $P < 0.0001$]
Table 2 Longitudinal neuropsychological test data for DAT patients at year 1 and year 2, and for controls (with SDs), with significance levels (P-values)

<table>
<thead>
<tr>
<th></th>
<th>Controls (n = 30)</th>
<th>DAT(^1) (n = 24)</th>
<th>DAT(^2) (n = 24)</th>
</tr>
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<tbody>
<tr>
<td><strong>Public</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF recognition</td>
<td>43.0 (6.7)</td>
<td>37.2 (10.1)*</td>
<td>39.8 (9.6)</td>
</tr>
<tr>
<td>FF identification</td>
<td>39.3 (8.8)</td>
<td>25.5 (10.6)**</td>
<td>21.5 (11.0)**</td>
</tr>
<tr>
<td>FF naming</td>
<td>31.1 (9.0)</td>
<td>10.4 (7.4)**</td>
<td>9.4 (7.8)</td>
</tr>
<tr>
<td>FN recognition</td>
<td>49.7 (0.7)</td>
<td>48.0 (2.7)**</td>
<td>47.1 (3.2)</td>
</tr>
<tr>
<td>FN identification</td>
<td>49.1 (1.3)</td>
<td>40.4 (6.1)**</td>
<td>32.1(9.0)**</td>
</tr>
<tr>
<td><strong>Autobiographical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMI—semantic</td>
<td>60.0 (3.5)</td>
<td>45.0 (10.8)**</td>
<td>42.0 (10.6)</td>
</tr>
<tr>
<td>AMI—incident</td>
<td>21.7 (5.0)</td>
<td>11.1 (6.6)**</td>
<td>10.4 (6.6)</td>
</tr>
<tr>
<td>ABF—names</td>
<td>26.8 (10.9)</td>
<td>8.7 (5.4)**</td>
<td>7.6 (5.0)</td>
</tr>
<tr>
<td>ABF—events</td>
<td>16.5 (7.0)</td>
<td>6.4 (5.0)**</td>
<td>6.1 (4.1)</td>
</tr>
</tbody>
</table>

FF = famous face; FN = famous name; AMI = Autobiographical Memory Interview; ABF = autobiographical fluency. *P < 0.05; **P < 0.01; ***P < 0.001; \(^1\) Significance levels at year 1 refer to difference between DAT patients and controls, analysed by unpaired comparisons. Significance levels at year 2 refer to difference between patients at years 1 and 2, i.e. paired comparisons.

Table 3 Correlation between autobiographical memory and memory for public figures in DAT patients

<table>
<thead>
<tr>
<th></th>
<th>FFR</th>
<th>FFI</th>
<th>FFN</th>
<th>FNR</th>
<th>FNI</th>
<th>AMI(^p)</th>
<th>AMI(^i)</th>
<th>ABF(^n)</th>
<th>ABF(^e)</th>
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<td>AMI(^i)</td>
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<td>0.22</td>
<td>0.28</td>
<td>0.17</td>
<td>0.36</td>
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<td>-0.06</td>
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<td>0.69**</td>
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<td>ABF(^e)</td>
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<td>0.39</td>
<td>0.41</td>
<td>0.59**</td>
<td>0.44*</td>
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</table>

FFR = famous face recognition; FFI = famous face identification; FFN = famous face naming; FNR = famous name recognition; FNI = famous name identification; AMI\(^p\) = Autobiographical Memory Interview—personal semantic; AMI\(^i\) = Autobiographical Memory Interview—incident; ABF\(^n\) = autobiographical fluency for names; ABF\(^e\) = autobiographical fluency for events. *P < 0.01; **P < 0.001.

Table 4 Summary of loadings for public and autobiographical memory in DAT patients after principal components factor analysis

<table>
<thead>
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<th>Factor 1</th>
<th>Factor 2</th>
<th>Final communality estimate</th>
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<tr>
<td>Famous face identification</td>
<td>0.92</td>
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<td>0.84</td>
</tr>
<tr>
<td>Famous name identification</td>
<td>0.89</td>
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<td>0.82</td>
</tr>
<tr>
<td>AMI—personal semantic</td>
<td>-0.05</td>
<td>0.91</td>
<td>0.83</td>
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<tr>
<td>AMI—incident</td>
<td>0.31</td>
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<td>0.78</td>
</tr>
<tr>
<td>Magnitude of eigenvalue</td>
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<td></td>
</tr>
<tr>
<td>Variance proportion</td>
<td>0.49</td>
<td>0.32</td>
<td></td>
</tr>
</tbody>
</table>

AMI = Autobiographical Memory Interview; ABF = autobiographical fluency.

and a significant interaction \[F(2,92) = 5.3, P < 0.01\]. Post hoc pairwise comparisons show that this was due to a longitudinal deterioration in performance on identification \(P < 0.001\), but not recognition or naming (both \(P > 0.05\)) (see Table 2 and Fig. 1).

A similar analysis for famous names revealed an effect for group \[F(1,46) = 10.2, P < 0.01\], condition \[F(1,46) = 172, P < 0.0001\] and a group by condition interaction \[F(1,46) = 18.2, P < 0.0001\]. Post hoc pairwise comparisons showed that this was a result of DAT patients deteriorating significantly on famous name identification over 1 year, but not on name recognition.

At a cognitive level, the longitudinal deterioration in identification of faces and names is consistent with a breakdown in central semantic knowledge regarding famous figures. The relative preservation of face and name
recognition, and face naming, argues that face and name recognition units, and the post-semantic lexicon were not further impaired by DAT in the year of study.

A more sophisticated means of analysing our longitudinal data at a cognitive level is by adopting an item-by-item approach; we can compare each patient's performance for each famous face longitudinally, which allows us to circumvent the problem of not being sure of the extent of subjects' premorbid knowledge of famous people which bedevils studies of remote memory.

Contingency tables for longitudinal results of each of the components of face and name processing are shown in Table 5. The recognition tasks were excluded since these employed a forced choice recognition paradigm. As forced choice introduces the possibility of guessing, we felt that we could not draw firm conclusions from our longitudinal study of recognition. Identification and naming did not involve a forced-choice paradigm.

Prior to presenting our data, we wish to state certain assumptions we have made regarding what our data tells us about the relative contributions of storage and access deficits. If an item is identified correctly at year 1 but not at year 2, this may be due to loss of storage of semantic knowledge regarding this famous person, or alternatively it may simply be due to a retrieval deficit occurring at year 2 but not at year 1. In the opposite circumstance, where the subject cannot identify the famous person at year 1, but can do so at year 2, then this is unlikely to be due to a storage system defect, but is more easily explained by a retrieval deficit. It is reasonable to assume that retrieval deficits are as likely to cause impaired identification at year 1 (but not year 2), as they are to cause impaired identification at year 2 (but not year 1). Thus, in a crude manner, we can try to allow for the effect of retrieval deficits to produce a measure of how much of the longitudinal deterioration in knowledge of famous persons is genuinely due to loss of semantic information. We admit, however, that these assumptions are simplistic to a degree. It may be difficult to separate storage and retrieval, in that a partial storage deficit will also make retrieval more difficult. On the other hand, a pure retrieval deficit might be expected to lead to identification being normal at year 1 but not year 2, but could also give the opposite pattern of identification being impaired at year 1 but normal at year 2. It is also conceivable that a pure retrieval deficit, worsening over a year, could lead to an overall deterioration on identification, which might be misinterpreted as being supportive of a storage deficit. It can be seen, therefore, that it is not possible to draw absolute conclusions regarding the relative contributions of storage and retrieval, but we can make a few tentative deductions from our data.

For famous face identification, overall performance fell from 544 to 379 patient-faces over a year, a drop of 165. It can be seen that there were, however, 208 instances of a face being correctly identified at year 1 and wrongly identified at year 2. There were 43 instances of wrong identification at year 1 but correct identification at year 2. These improved responses are likely to be due to retrieval errors at year 1, rather than loss of knowledge. To control for retrieval deficits contributing to correct score at year 1 but incorrect identification at year 2, we can subtract 43 cases from the 208, leaving 165 cases of loss of identification over a year which are likely to be due to loss of semantic knowledge of the famous face. The ratio of retrieval deficits in year 1 to loss of information from year 1 to 2 was, therefore, 43:165, or ~1:4. Although by no means conclusive, our data suggest that the deterioration in semantic knowledge regarding famous
people is primarily due to a loss of storage rather than a deficit in access.

The deterioration in famous face naming was less marked than for identification. Overall, naming fell from 245 correct on year 1 to 224 on year 2, a drop of 21. There were 105 instances of loss of correct naming over 1 year, but 84 with the opposite effect. Thus face naming data are suggestive of significant retrieval deficits at years 1 and 2. There was, however, little evidence of a significant deterioration in face naming over the year.

Our findings on the identification component of the faces test were largely mirrored by performance on famous names. Famous name identification fell from 921 correct responses on year 1 to 605 on year 2, a fall of 316. The total number of responses changing from correct to incorrect was 344, with only 28 changes in the opposite direction: a ratio of 28:344, i.e. ~1:10. This would suggest that the deterioration in famous name identification over the year could be attributed largely to loss of storage of famous names rather than to retrieval deficits.

We were puzzled by the deterioration in face identification but not naming, given that naming is dependent on semantics. We postulate that cases showing longitudinal deterioration in identification may have had impaired naming in the first instance. We analysed, therefore, naming in all instances where identification had declined over 1 year. Unpaired comparisons confirmed that, in those subject-faces where face identification became impaired over 1 year, there were significantly more instances of initially impaired naming of the same face than of intact naming (t = 2.98, P < 0.01). This, at least, partly explains the somewhat anomalous finding of longitudinal deterioration in identification but not naming, without having to postulate the existence of naming without semantics (Kremin, 1986; Shuren et al., 1993; Kremin et al., 1994). This conclusion is further strengthened by our finding that, in 1200 individual presentations of a famous face to a DAT subject, there were no instances in which the subject could not provide semantic identifying information of the famous face while being able to produce the name.

Fractionation of remote memory
Our co-administration of tests of public and autobiographical memory allowed us to address the issue of the fractionation of remote memory over time.

To summarize findings on autobiographical memory, paired comparisons of performance at year 1 and 2 on tests of autobiographical memory showed no deterioration on any of the autobiographical tests (P > 0.05) (see Table 2 and Fig. 2). This lack of deterioration is in contrast with that noted above for public memory, and is further evidence that these subcomponents of remote memory are dissociable.

Another means of addressing the relationship between public and autobiographical memory is to ascertain the percentage change over 1 year for the various subtests. If public and autobiographical memory were not dissociable, then we would expect deterioration in public memory to be invariably accompanied by a similar deterioration in autobiographical memory. Table 6 shows that such a relationship was not observed; the deterioration in famous face identification correlated significantly with the deterioration on the incident component of the AMI, but no other relevant correlations were found.

Finally, our group data may be complemented by a multiple single case approach. Figure 3 illustrates the decline in public and autobiographical memory tests over 1 year. Each column represents a single patient; the patients have been ordered by disease severity as defined by the MMSE score at year 1. As mentioned in the Methods section, autobiographical and public memory Z-scores for years 1 and 2 are derived. It can be seen that the decline in public memory performance is not always mirrored by a decline in autobiographical memory. For example, Patient X shows a much greater deterioration in public memory than autobiographical memory. By contrast, Patient Y shows a mild decline in autobiographical memory but not for public memory. It is apparent that in most patients, the decline in public memory is greater than for autobiographical memory.

Our results are in keeping with the separability of public and autobiographical memory. A multiple single case approach has highlighted instances of decline in public but not autobiographical memory (e.g. Patient X). The contrasting pattern of decline in autobiographical but not public memory has not been convincingly shown, although some patients show a trend towards this (e.g. Patient Y). Although we have fallen short of showing the double dissociation that would prove convincingly the separability of these subcomponents of remote memory, we have nevertheless illustrated that
J. D. W. Greene and J. R. Hodges

Fig. 3 Univariate scattergram of performance by the DAT patients at year 2 compared with their performance at year 1 on tests of public and autobiographical memory (ABM), ordered by increasing dementia severity (as determined by MMSE).

Table 6 Correlation matrix based on percentage change in public and autobiographical memory over 1 year in DAT patients

<table>
<thead>
<tr>
<th></th>
<th>FFR%</th>
<th>FFI%</th>
<th>FFN%</th>
<th>FNR%</th>
<th>FNI%</th>
<th>AMIp</th>
<th>AMI i</th>
<th>ABF n</th>
<th>ABF e</th>
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<td>FFR%</td>
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</tr>
<tr>
<td>FNI%</td>
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<td>0.63*</td>
<td>0.41</td>
<td>0.68**</td>
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<tr>
<td>AMIp</td>
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<tr>
<td>AMI i</td>
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<td>0.02</td>
<td>0.39</td>
<td>0.23</td>
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</table>

Percentage change in: FFR% = famous face recognition; FFI% = famous face identification; FFN% = famous name recognition; FNR% = famous name recognition; FNI% = famous name identification; AMIp = AMI—personal semantic; AMI i = AMI—incident; ABF n = autobiographical fluency—names; ABF e = autobiographical fluency—events. *P < 0.01; **P < 0.001.

deterioration in public memory and autobiographical memory are not invariably linked.

Discussion

Studies of remote memory have been plagued with methodological difficulties, due primarily, to difficulty in ascertaining the premorbid databases of autobiography and knowledge of public figures and events once carried by the DAT subjects. By extending our cross-sectional study of remote memory in DAT longitudinally, thereby using the patients as their own controls, we have attempted to overcome such difficulties. Our inquiry has focused on two issues in particular: the fractionation of remote memory, and a cognitive analysis of the nature of the remote memory deficit.

In summary, we have confirmed that autobiographical and public memory are both impaired in DAT. There was evidence of longitudinal deterioration in public memory but not autobiographical memory, supporting the fractionation of remote memory into autobiographical memory and memory for famous people. At a cognitive level, the deterioration in public memory was due to impairment at the level of famous face and name identification. The loss of identification appeared to be due, largely, to loss of storage of semantic
information, whereas the naming deficit occurred as a result of impaired retrieval. We will now address these points in more detail.

**Fractionation of remote memory**

Our cross-sectional data confirm previous work showing that both public and autobiographical memory are impaired in DAT (Sagar et al., 1988; Dall'Ora et al., 1989; Kopelman, 1989; Hodges et al., 1993; Greene and Hodges, 1995; Greene et al., 1995). We have extended this and found evidence of longitudinal deterioration in famous face and name identification, but no such deterioration for autobiographical memory. These findings are in keeping with the growing number of single-case reports highlighting the separability of public and autobiographical memory. This implies that these two domains of remote memory are functionally, and presumably anatomically, distinct.

One potential reason for an apparent dissociation between autobiographical and public memory might be differing levels of task difficulty between the public and autobiographical memory tests. This could lead to the occurrence of 'floor effects' or 'ceiling effects' on one (or other) task, and produce an apparent dissociation between public and autobiographical memory tests which might, in fact, be artefactual due to differing test difficulty. It can be seen from Figs 1 and 2, however, that there is no evidence of ceiling or floor effects in the DAT subjects on either the public or autobiographical tests. The differential decline appears, therefore, to be a real rather than artefactual finding.

The process of retrieving autobiographical memories requires problem solving, checking and verification, and depends upon so-called thematic retrieval frameworks (Conway and Bekerian, 1987; Hodges and McCarthy, 1993). Autobiographical memories are multi-faceted with visual, verbal and other components: except in the case of over-rehearsed and flashbulb memories, their revocation is an active process which almost certainly requires the participation of frontal systems acting on widely distributed areas of posterior temporo-parietal cortex. This clearly differs in representation and organization from memory for public figures (Baddeley, 1992). Recalling information about a famous person from their name or face is a less re-creative process and appears to be relatively independent of frontal executive function (Hodges and McCarthy, 1995). Memory for public figures appears to rely on right temporal structures (Ellis et al., 1989; Hanley et al., 1989; Evans et al., 1995). Our finding of deterioration in public, but not autobiographical, memory is in keeping with this broad subdivision of remote memory.

It should be stated that not all remote memories can be classified as exclusively autobiographical or public. For example, seeing a politician when on holiday in London (autobiographical) and seeing the same politician on television news (public), are likely to call on overlapping resources. Although we admit that autobiographical and public memory are likely to overlap, we feel that certain kinds of memories are likely to be very largely one or other, and that our tests do investigate predominantly autobiographical and predominantly public memory. Our understanding of remote memory is perhaps best accommodated by a model in which autobiographical and public memory draw on largely discrete cognitive, and hence neural, processes, but share some information in common.

We have used DAT as an experimental model to study the theoretical issue of the fractionation of remote memory. We do not, however, mean to imply that autobiographical memory is preserved in DAT. Indeed, our cross-sectional data shows that this is not so (Greene et al., 1995). In a disease showing insidious progression, such as DAT, it is likely that all subcomponents of memory will eventually deteriorate. Different components of memory will, however, decline at different stages in the illness and at different rates, depending on the sites of pathological involvement at particular stages of the disease. We would only say that in the experimental setting of studying minimal to mild DAT patients over 1 year, there was evidence of a differential decline between autobiographical and public memory, suggestive of fractionation within remote memory. Clearly, continuing the longitudinal assessment of autobiographical and public memory over a longer time period would answer the issue more definitively.

**Cognitive analysis of face and name processing: storage versus access**

Turning now to the cognitive analysis of famous face and name processing, our results indicate that the bulk of the deterioration over 1 year in DAT is at the identification stage. By contrast, the same patients' ability to recognize faces and names from among closely matched foils did not decline. When interpreted in the context of the cognitive models of face and name processing outlined above (Bruce and Young, 1986; Valentine et al., 1991), these findings suggest that there has been a progressive deterioration in semantic knowledge of famous people accessed from face or name, but with no deterioration in face or name recognition units. The finding that semantic knowledge, whether accessed by face or name, decline in parallel, suggests that face-derived and name-derived identification are drawing on the same store of semantic knowledge of the public figures.

If naming is dependent on semantic knowledge, as we have argued above, it is surprising that the deterioration in identification was not accompanied by a similar deterioration in naming. As discussed in the Results section, one might plausibly explain this finding on the basis that naming was usually already impaired at year 1 in those instances where longitudinal deterioration in identification occurred. This would explain our findings without invoking the existence of naming without semantics (Kremin, 1986; Shuren et al., 1993; Kremin et al., 1994). As already mentioned, there was...
not a single instance of correct face naming in the absence of semantic identifying information, which strongly argues against naming without semantics, at least for public figures.

Some researchers have claimed that the deficits found on tests of general semantic memory in DAT may primarily reflect impaired access (for reviews, see Nebes, 1989; Bayles et al., 1991), but the majority of investigators support the explanation which hypothesizes a breakdown in the structure of semantic memory (Martin and Fedio, 1983; Chertkow and Bub, 1990; Hodges et al., 1992b; Chan et al., 1993). For instance, in both the studies by Chertkow and colleagues (Chertkow and Bub, 1990; Chertkow et al., 1992) and that by Hodges et al. (1992b) there was a highly significant item-by-item correspondence between DAT subjects' performance on picture naming and on other tests designed specifically to probe for semantic knowledge about the same items. This is, however, a controversial topic since item-by-item consistency, previously taken as evidence for a storage problem, may also result from impaired access (Funnell and Hodges, 1991), thus muddying the storage versus access issue (Rapp and Caramazza, 1993). Indeed, the whole issue of separating the contributions of storage and retrieval to semantic memory impairment have been somewhat sidelined by the development of distributed representational networks, which blur the distinction between storage and access (Rumelhart et al., 1986; McClelland et al., 1995): partial damage, with a loss of a certain volume of connections or representations from a network, may produce an apparent 'retrieval' deficit, while a small amount of additional damage to critical units or connections could cause the more classic pattern associated with storage loss. That said, in our study there was evidence that a retrieval deficit made only a minor contribution to the identification impairment in our study, and that the bulk of the semantic impairment for face and name identification appeared to be due to loss of knowledge, in keeping with previous studies of remote memory in DAT (Hodges et al., 1993).

It is interesting, however, that there was considerably more variability from year 1 to year 2 on the naming component of the faces test: overall performance fell by 21 person-faces but there were 105 instances of change from correct to incorrect over 12 months and 84 instances of change in the opposite direction. Thus, it would appear that although decline in identification represents a genuine loss of information (once patients are unable to describe the person, the deficit remains), impaired retrieval contributes significantly to the anoma. This finding goes some way towards explaining the controversy over the issue of storage versus retrieval loss in DAT: both are important but they contribute differentially to the semantic deficit and the name retrieval disorder for famous faces.

Acknowledgements

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Appendix

1940s
Louis Mountbatten
Joseph Stalin
George Formby
Bing Crosby
Vera Lynn
Dwight Eisenhower
Clement Attlee
Aneurin Bevan
Groucho Marx
Lord Montgomery

1950s
Diana Dors
Richard Dimbleby
Grace Kelly
Harold MacMillan
Arthur Askey
Anthony Eden
Gilbert Harding
Rab Butler
Anthony Crossland
Pandit Nehru

1960s
John Profumo
Harold Wilson
Tony Hancock
Peter Sellers
Barbara Castle
Sid James
Hughie Green
Alec Douglas Home
Sean Connery
Sophia Loren

1970s
Michael Foot
Ayatollah Khomeini
Ian Botham
James Callaghan
Indira Gandhi
Jimmy Carter
Ken Livingstone
Elton John
Glenda Jackson
Michael Parkinson

1980s
Ronald Reagan
Esther Rantzen
Sarah Ferguson
Michael Heseltine
Arthur Scargill
Neil Kinnock
Steve Davis
Terry Wogan
Mikhail Gorbachev
Dame Edna Everage