Alzheimer's disease, but not ageing or depression, affects dual-tasking

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Abstract Two experiments are reported that assess dual task performance in Alzheimer's disease (AD), in chronic depression and in healthy old age. Results suggest that dual task impairments are present in AD but are not shown in depression. This is true even when episodic memory performance is equated between the groups. These results, together with those of previous studies, point to dual task performance as an aid to diagnosis of AD relative to depression. This is of particular relevance when episodic memory tests cannot distinguish between the two conditions. The dual task paradigm appears to have considerable promise in assisting the early detection of the specific cognitive deficits associated with AD, and in monitoring their progression, both in the laboratory setting and in everyday tasks. Results also are of theoretical interest in pointing to a specific dual task coordination function in the healthy human cognitive system that allows for the coordination of two tasks performed simultaneously and which is damaged in AD but not in depression.

Keywords Dual task, Alzheimer's disease, Depression, Episodic memory

Introduction

In a clinical setting, to discriminate between early Alzheimer's disease (AD) and chronic depression in the elderly still presents considerable challenges [8, 16, 18, 46, 48]. The two conditions feature overlapping cognitive symptoms [7, 10], which spread through different cognitive domains [33, 55]. The cognitive hallmark of AD is widely considered to be a deficit in episodic memory [17, 45], and several memory tests have been proposed as suitable candidates for differentiating AD from depression. These include free delayed recall [28], rate of forgetting [55], recognition paradigms [e.g., 38] or the serial position curve [22]. However, none of these measures appear to combine sensitivity with specificity for AD when subjected to rigorous tests [20, 23, 32]. Cued recall has also been proposed as another possible memory paradigm that could characterise AD [17, 49]. Indeed, there is one study of which we are aware reporting that cued recall can discriminate between AD and depression [16]. Although promising, these results are complicated by the fact that the depressed patients included in the study (but not the AD patients) were under treatment with antidepressants which are known to improve performance on hippocampal-related tasks such as cued recall [25], so this does not offer sufficient specificity to aid differential diagnosis.

Finally, the paired associate learning task from the CANTAB has been reported to be particularly sensitive to AD and much less so to depression [9, 21, 48].

Although not explicitly acknowledged by the authors, this particular paired associate learning task from the CANTAB is in fact a dual-task requiring participants to remember a series of visual patterns while at the same time processing their relative locations [see 43]. In our previous work we have demonstrated that dual-task co-ordination is specifically affected by AD when compared to normal ageing [3–5, 15, 36, 39]. Therefore, given the possible sensitivity but lack of specificity of episodic memory tasks to AD, and the possible specificity of dual-tasking to AD, we set up a study to investigate whether a dual-task paradigm could assist the clinical differentiation between AD and chronic depression. A further advantage of this approach is that dual-task performance can be studied within the context of theories of cognition. Such theories offer a basis for selecting the methods of assessment, monitoring progression of the disease and evaluating the effectiveness of treatments. The theoretical framework of working memory has been particularly fruitful in the study of cognitive deficits observed in AD patients pointing to specific impairments in the ability to perform two tasks concurrently. Working memory refers to on-line human cognition including short-term visual and verbal memory and co-ordination of dual task performance as well as a range of other cognitive functions [2, 37, 41]. It is the dual task co-ordination function that is the focus of the current paper.

In our previous work [e.g. 36, 39] AD patients, healthy older participants age matched with the patients, and healthy younger participants education matched with the other two groups, first were assessed on their ability to perform each of two single tasks involving, respectively perceptuo-motor tracking and immediate serial recall of aurally presented digit sequences. The demands of each task were adjusted (titrated) so that individuals performed the tasks at their own ability limits under single task conditions. Participants were then asked to perform both tasks concurrently at the demand level determined by the titration and used in the single task conditions. Typically, the AD patients showed a dramatic drop in overall performance levels under dual task conditions, while healthy older people showed the same relatively modest dual task effect that is shown by younger participants. Because single task differences were removed through the titration procedure, this differential effect in the patient group cannot be attributed to differences between the groups in single task performance. Even when the demands of the concomitant tasks are much lower than the patient's individual ability levels, a dual task decrement is found, while increasing the demand of a single task has almost identical effects on patients and control participants [36]. Moreover, dual task performance in AD deteriorates further with the progression of the disease [3]. The specific dual task impairment in AD has been shown with different combinations of computer based tasks [e.g. 2, 39], paper and pencil tasks [14, 27] as well as in everyday tasks such as keeping track of group conversations [1] or walking while talking [11]. Findings have also been replicated in other laboratories [e.g. 24, 26, 47]. These results suggest that the dual task effect observed in AD is independent of overall cognitive demand [36], and also independent of the well established episodic memory deficit in such patients [44]. Importantly, they also suggest that, unlike the episodic memory deficit, the dual task impairment is specific to AD and does not appear in normal ageing (for a discussion see [39]). The paradigm would therefore appear to have considerable promise in assisting the early detection of the cognitive deficits associated with AD and in monitoring their progression, both in the laboratory setting and in everyday tasks.

Although the dual-task impairment proved to be specific to AD when compared to healthy older people, its specificity has yet to be investigated with respect to other disorders affecting cognitive performance in the elderly and which may be misdiagnosed as early stage AD, most notably depression. However, there are hints from previous studies that people with depression might not have difficulty with performing two tasks concurrently [e.g. 34]. For example, Lachner and Engel [35] showed that AD patients, but not depressed people, show a particular difficulty in dealing with a distraction during a memory task, which is essentially a dual task paradigm [see e.g. 12], even if the original authors do not describe it as such. Swainson et al. [48] reported that tests assessing memory for related information

discriminated mild AD from other conditions including depression and normal ageing. However, close scrutiny of Swainson et al.'s data shows that only memory for tasks that require combinations of different features in different locations was differentially affected by early stages of AD [see also 43], thus supporting the notion that dealing with more than one task at a time is affected by AD but not by depression.

Williams et al. [53] have shown that the addition of a secondary task appears to improve psychomotor reaction times of clinically depressed patients. The good performance in dual-task paradigms would be particularly relevant given that people with depression frequently show impairments in other tests of executive functions [meta-analysis in 50], an observation also reported in depressed older people [5]. However, the apparent lack of a dual task deficit in depressed patients has yet to be established, given that the only available studies did not directly address concurrent dual task performance,[1] the tasks chosen were not theoretically motivated, and those particular paradigms have not been used in assessing AD.

The primary aim of the present study was to assess dual task performance in elderly people affected by chronic depression as compared to people with AD and matched controls. Throughout, the focus is on dual task performance, while controlling for group differences in episodic memory.

Experiment 1

Method

Participants A sample of 89 participants from three groups were recruited for the study, namely people diagnosed with AD, people with chronic depression, and a group of healthy elderly individuals. Details of the three groups are depicted in Table 1. There were no significant differences between the groups in age and years of formal education.

AD patients Twenty-two patients (12 men, 10 women) attending the Memory Clinic at the University Department of Psychiatry in Giessen (Germany) were selected. The diagnostic criteria from the NINCS-ADRDA for probable AD [40] were followed, including medical, neurological and neuropsychological screening to rule out any other possible dementias. None had a history of other neurological or psychiatric diseases or of alcohol or drug abuse. All patients included in the sample showed clear evidence of cognitive deterioration over a period of at least 6 months following the experimental testing session. Demographic details are given in Table 1 along with scores on the mini mental state examination (MMSE) [19] and on the Beck depression inventory (BDI) [6]. From the table it is clear that the AD patients were within the normal range on the BDI and were not suffering from depression.

Patients with depression Forty-three patients (21 men, 22 women) were diagnosed by experienced psychiatrists as having suffered a chronic condition of depression with remission periods that were never longer than 1 month. Of these, 31 patients had suffered from the chronic condition of dysthymia, whereas 12 patients had a chronic stage without a symptom-free period (remission) within the course of a major depression disorder lasting for at least the previous 10 years. Other diagnostic subtypes within the ICD-10 [54] category were excluded (e.g., late-onset depression with white-matter lesions in MRI; bipolar type of depression; depression caused by serious physical or psychosocial stress). The patients had no history of other psychiatric or neurological diseases or of alcohol or drug abuse. Demographic, MMSE

and BDI details are shown in Table 1 from which it is clear that these participants were not suffering from dementia and were scoring within the range of clinical depression.

Control participants Twenty-four healthy participants (9 men, 15 women) were also tested, recruited from among hospital volunteers and spouses or relatives of patients. Details are shown in Table 1. They showed no signs of, and had no history of, current or previous psychiatric or neurological diseases.

Materials

Episodic memory assessment Episodic memory was assessed using the "Appointments" test [29, 30]. This comprised a list of eight appointments, presented on paper, and which participants had to learn over a period of 2 min. There was then a delay of 45 min during which participants completed a battery of standard cognitive ability tests none of which involved memory. This comprised several subtests of the Wechsler adult intelligence scale, followed by problems using the Tower of Hanoi in its four-disc version. Demanding tasks were chosen in order to minimise covert rehearsal of the appointments. Following the filled delay, participants were asked to recall the appointment list in any order. Delayed recall was used because this has been shown to be a measure of episodic memory that is particularly sensitive to AD (e.g. 13). The appointments test was completed prior to, and in the same testing session as the dual task assessment (see below). No feedback was given regarding accuracy of the answers nor were there any hints or cues for recall.

Each of the eight test items consisted of four parts (e.g., "Tuesday/between 11 and 12 a.m./ring Tom/in Manchester"), and correct recall of each part was given a score of one, thus yielding a total score range of 0–32 (i.e., eight appointments with four parts each—$8 \times 4 = 32$). One part was counted as correct if it was semantically identical to the appointment presented. For example, if only "11 o'clock" was recalled instead of "between 11 and 12 a.m." no credit was given. Previous standardisation of this test showed that independent scorers showed a high level of agreement ($r = 0.97$), good internal consistency (Cronbach-Alpha = 0.80) and test-retest reliability ($r = 0.78$) [31]. The test proved to be sensitive enough to detect deterioration over time in mild cognitive impairment [51] and improvement after memory training [29, 52].

Dual task assessment Assessment of dual task performance involved measuring the ability of each participant on recall of aurally presented digits and on visuo-spatial tracking, both as single tasks and with the two tasks performed concurrently. As noted in the introduction, ideally, assessment of dual task performance should include titration of the demand for each single task according to the capacity of each individual. This is possible with digit recall (see below), and was possible with a previous, computerised version of the tracking task [4, 36]. However, with paper and pencil tracking, titration can only be based on comparing percentage change in performance between single and dual task [for a discussion see, 14]. The materials for the tracking task that we used in the present study, and the full instructions for administration and scoring for the single and dual task assessment can be found at: www.psy.ed.ac.uk/people/sdsala/tests/sdsdualtask/.Core details of the tasks are given below.

Digit span

To assess capacity for digit recall for each participant, first the experimenter read aloud random digit sequences at a rate of one digit per second for immediate oral, serial recall. The initial sequence length was three digits and participants were presented with six sequences at each sequence length. If at least five

out of the six sequences were correctly recalled, the digit sequence was increased by one digit. Capacity (digit span) was taken as the maximum sequence length at which a given participant was able to reliably recall five out of six sequences.

Digit recall

Each participant was presented with sequences set at the length of their own span for immediate serial oral recall. This task continued with different sequences over a period of 90 s. The number of sequences completed within 90 s varied according to the length of each participant's span. Performance was measured in terms of the proportion of digits recalled in the correct serial position across all of the sequences completed.

Tracking

The tracking task consisted of using a pencil to draw a line through a series of circles arranged along an irregular path around a sheet of A3 paper. Participants were given a shortened version for a practice trial, with only 17 circles, to ensure that they understood the task demands. After this, the participant was presented with the full version, comprising 319 circles. They were asked to start at one end of the path and draw a line through each successive circle as quickly as they could within 90 s. The performance measure was the number of circles crossed within the allotted time.

Procedure

After assessing the digit span for each individual ('titration'), single task tracking was performed followed by digit recall as a single task. Next, two dual-task trials (tracking plus digit recall) were carried out, each lasting 90 s. Finally, the two single tasks (digit recall alone and tracking alone) were repeated. This procedure of single tasks, then dual tasks and then single tasks again was adopted to take account of any possible changes in performance that arose from practice or fatigue because of performing the single tasks before the dual task condition. Therefore single task scores were based on an average of performance from single task before and single task after dual task. Dual task score comprised the average of the two dual task trials.

Results

The episodic memory tests were included primarily to assess whether any differences between groups in dual task sensitivity could be explained in terms of episodic memory ability. Summary data are shown in Table 2. An analysis of these episodic memory data showed that depressed ($M = 10.0$, $SD = 6.2$) and elderly control ($M = 9.7$, $SD = 4.8$) participants did not differ, $t(65) = 0.22$, ns, and that both the depressed and control group had significantly better performance than the AD patients ($M = 0.5$, $SD = 0.7$): $t(63) = 7.18$, $P < 0.001$ (depressed vs AD) and $t(44) = 8.85$, $P < 0.001$ (control vs AD). Therefore, episodic memory performance was included as a covariate in the analysis of dual task performance. Single task digit recall performance did not differ across groups $F(2, 85) = 2.00$, ns, partial $\eta^2 = 0.045$, neither did single task tracking performance $F(2, 85) = 3.11$, ns, partial $\eta^2 = 0.068$.

Calculation of dual task cost scores

The dual task percentage cost for digit recall was calculated as digit recall score in dual task conditions divided by digit recall score in single task conditions ×100 (see Table 2). For example, a score of 80 corresponds to a dual task cost of 20%, or a drop of 20% between single and dual task performance.

The dual task cost for tracking was calculated in the same way, namely tracking score in dual task conditions divided by the tracking score in single task conditions ×100.

The Levene test of homogeneity of variance indicated that the digit recall single task score was negatively skewed. Therefore the data were transformed by subtracting all values from the highest value plus 1 and then performing a square root transformation. This resulted in normally distributed data which were used in the analysis. None of the other measures violated assumptions of homogeneity.

Dual-task costs across the three groups (AD, depressed, healthy controls) were subjected to an ANCOVA with episodic memory scores entered as a covariate.

The dual task cost for tracking performance differed across groups $F(2, 84) = 7.44$, $P < 0.001$, partial $\eta^2 = 0.15$. Bonferroni-corrected post hoc comparisons showed that Alzheimer patients performed more poorly than controls (mean difference −1.745; $P < 0.001$) and than depressed elderly (mean difference −1.771; $P < 0.002$), whereas controls and depressed elderly did not differ (mean difference −0.026; ns).

Digit recall dual task performance did not differ significantly across groups $F(2, 85) = 2.50$, ns, partial $\eta^2 = 0.056$.

The most relevant measure for assessment of overall dual task costs comprised the mean of the two previous scores, i.e. the average of the dual task digit recall and dual task tracking costs. The scatterplot of these overall scores for the three groups is shown in Fig. 1. This shows that there is a complete overlap between controls and depressed participants, whereas the overall dual task performance of a sub group of AD patients is clearly very different. The ANCOVA on the combined dual-task score yielded a significant effect of group: $F(2, 85) = 5.45$, $P < 0.001$, partial $\eta^2 = 0.114$. Bonferroni-corrected post hoc comparisons indicated that AD patients showed a significantly higher overall cost of dual task than the depressed elderly (mean difference 1.057; $P < 0.004$) and than normal controls (mean difference 0.862; $P < 0.05$), whereas normal and depressed elderly did not differ (mean difference −0.195; ns).

Figure 2a–c plot receiver operating characteristic (ROC) curves [*56*] illustrating the sensitivity and specificity of the overall dual task cost measure in comparing the performance across the three groups. The main diagonal line in each figure illustrates the expected values if the test were to be both insensitive and lacking in specificity in discriminating between the groups being compared. This would yield an area under the curve of 0.50. Figure 2a illustrates that the test is both sensitive and specific in discriminating between the AD group and controls. The area under the curve is 0.81 (SE = 0.06), which is significant ($P < 0.001$). 95% confidence intervals are 0.69 (lower bound) and 0.93 (upper bound). Figure 2b shows a similar pattern when comparing the performance of AD patients relative to that of depressed patients. The area under the curve is 0.84 (SE = 0.05), which is significant ($P < 0.001$). 95% confidence intervals are 0.75 (lower bound) and 0.94 (upper bound). Figure 2c shows the ROC curve comparing controls and depressed participants. It is clear from the figure that the test does not discriminate between controls and depressed patients. The area under the curve is 0.43 (SE = 0.07), which is not significant ($P = 0.36$). 95% confidence intervals are 0.29 (lower bound) and 0.57 (upper bound), which include the chance score of 0.50.

Discussion

A comparison between AD patients, depressed people without AD and healthy controls showed that AD patients are differentially sensitive to the cognitive costs of concurrently performing a memory task and a tracking task. The presence of a dual task impairment in AD and the lack of such an impairment in healthy ageing has been shown in a number of previous studies [3, 14, 36, 39]. This is theoretically and clinically relevant; it points to a co-ordination function in the healthy brain that is impaired in AD, and it suggests a dissociation between AD and healthy ageing. The important, novel contribution from the current study is to show that the dual task effect in AD is specific, even when compared with a group whose symptoms often overlap, namely elderly with chronic depression. Indeed, the dual task performance of the depressed people did not differ from that of controls.

The results of Experiment 1 were clear. However, the AD patients recruited for participation showed a large impairment in episodic memory tasks relative to the other two groups. Therefore, although the results are theoretically relevant, the utility of adding the dual task procedure to clinical assessment is less clear. We addressed this issue in Experiment 2 involving new groups of AD patients and depressed elderly people, both of which showed evidence of memory problems.

Experiment 2

Experiment 2 was designed to address whether dual-task performance could discriminate between AD and depressed groups that do not differ in episodic memory performance.

Method

Participants We recruited 24 new depressed (11 male) elderly patients scoring at or above the clinical cut-off for depression in the Beck depression inventory (BDI ≥ 11 points) and complaining of memory problems. We also recruited 29 new AD patients (20 male) following the same selection criteria as for Experiment 1. Depressed patients had a mean age of 62.5 years (SD = 8.8, range 49–82). AD patients had a mean age of 65.5 years (SD = 9.5, range 46–86). This difference was not significant, $t(51) = 1.18$, ns. Years of education also did not differ (depressed M = 9.3; SD = 1.1; range 8–13 vs AD M = 10.3; SD = 2.9; range 5–18), $t(37, \text{adj.}) = -1.65$, ns. Digit span did not differ (depressed M = 4.29; SD = 0.96; range 3–6 vs AD M = 4.34; SD = 0.94; range 2–6), $t(51) = -0.2$, ns.

Self-ratings of depression using the BDI yielded significantly higher scores in the depressed as compared to AD patients (depressed M = 22.2; SD = 10.6; range 11–53 vs AD M = 7.0; SD = 6.0; range 0–25), $t(35, \text{adj.}^2) = 6.24$, $P < 0.001$. Using the mini-mental-state examination as an approximate measure of the degree of mental deterioration, depressed patients had significantly higher scores than AD patients (depressed M = 27.4; SD = 1.6; range 25–29 vs AD M = 23.7; SD = 3.9; range 13–29), $t(39, \text{adj.}) = 4.57$, $P < 0.001$. Notably, performance on episodic memory assessed with the Appointments test from Experiment 1 did not differ between the two groups (depressed M = 2.6; SD = 1.6; range 0–5 vs AD M = 1.7; SD = 2.2; range 0–8), $t(51) = 1.58$, ns.

Procedure The tasks and procedures from Experiment 1 were used here.

Results

A *t* test showed that single-task digit recall did not differ between the groups (depressed M = 94.1%; SD = 7.5% vs AD M = 91.7%; SD = 8.1%), t(51) = 1.1, ns, Cohen's d = 0.31. Under dual-task conditions there was a significant difference in digit recall in that depressed patients performed significantly better (M = 91.8%; SD = 6.8%) than the AD patients (M = 85.1%; SD = 11.1%), t(46, adj.) = 2.6, P < 0.02, d = 0.61.

In the tracking task a similar pattern emerged with no difference between groups on single task performance (depressed M = 170.4 circles; SD = 58.7 vs AD M = 150.6 circles; SD = 72.6), t(51) = 1.1, ns, d = 0.31 whereas depressed patients performed significantly better under dual-task conditions (M = 146.0 circles; SD = 51.1) than the AD patients (M = 102.9 circles; SD = 62.0: t(51) = 2.8, P < 0.01, d = 0.76. Dual task costs were calculated for tracking, digit recall and the combined dual task score using the same procedures as in Experiment 1.

A *t* test showed that depressed patients had significantly lower dual task cost in tracking (M = 85.8%; SD = 10.7) compared with AD patients (M = 68.3%; SD = 21.8; t(42, adj.) = 3.8, P < 0.001, d = 1.17.

Digit recall score showed a similar pattern. Depressed patients were significantly less impaired under dual-task conditions (M = 98.0%; SD = 7.6) compared with AD patients (M = 92.6%; SD = 7.9), t(51) = 2.53, P < 0.02, d = 0.79).

The most relevant measure, that is the combined dual task measure, yielded an even larger difference between depressed (M = 91.9%; SD = 6.6) and AD patients (M = 80.4%; SD = 11.9), t(45, adj.) = 4.4, P < 0.001, d = 1.31).

Discussion

In this second experiment, AD patients again showed a substantial dual task cost, while the depressed group showed minimal cost, equivalent to that shown by depressed and healthy participants in Experiment 1. More importantly, the impairment in AD dual task performance, relative to a group of individuals with chronic depression, was found even when memory performance was equated between groups. This reinforces the conclusion that dual task impairment is specific to AD, suggesting that dual task assessment offers added clinical value over and above tests of episodic memory.

Conclusions

Across two experiments, AD patients were shown to have a severe impairment in performing two tasks concurrently, in contrast to healthy older people who showed little if any cost of dual task in the same paradigm. This replicates and extends previous similar findings [3, 14, 36, 39]. Importantly, the two experiments also demonstrate the novel finding that people with depression showed dual task costs that were equivalent to those found for age-matched healthy participants (Experiment 1), even when episodic memory performance for the depressed group was the same as that shown by AD patients (Experiment 2). Therefore, the cost of dual task appears to be specific to AD and is not shown in patients whose symptoms are often difficult to discriminate from those with the disease.

In previous studies of dual costs in AD [3, 36, 39], typically both tasks have been titrated to match the single task abilities of each participant. However, the tracking task involved rather bulky and expensive equipment that required training for its use. In the present set of experiments, digit recall demands were adjusted as in those previous studies. The paper and pencil tracking task is portable and very easy to use with minimal training, but does not allow for titration of demand under single task conditions. Nevertheless, it proved to be highly usable in a wide range of clinical settings here and in previous studies [14], and we obtained the typical AD dual task deficit.

Taken together these results support the hypothesis of a specific dual task coordination function in the healthy human cognitive system that allows for the coordination of two tasks performed simultaneously, and that there is specific damage to this function in AD. Dual task coordination could be considered as one of a range of executive functions within a working memory system [3, 41] that is compromised possibly by damage to prefrontal cortex in AD [e.g. 2], or by disconnection through white matter atrophy in the disease [e.g. 42]. The results reported here suggest that the hypothesis of a co-ordination function may have value as an aid to diagnosis of AD, and to refine discrimination between AD and chronic depression. This is particularly relevant when episodic memory tests cannot distinguish between the two conditions. That is, episodic memory may be very sensitive to cognitive impairments associated with AD but is not sufficiently specific. Therefore the inclusion in the diagnostic toolbox of a form of assessment that adds specificity could increase the reliability of the clinical diagnosis of AD in addition to enhancing the theoretical understanding of core deficits in the disease.

Footnotes

[1] A recent paper by Lonie et al. (2008) used our own dual task procedures in studying patients with a range of depressive symptoms, MCI patients and AD patients as well as healthy older volunteers. However tracking task performance was less than half that for all other studies, and they obtained ceiling effects on single task digit recall for the tests in all groups making it very difficult to interpret the data.

[2] In cases in which the Levene test for equivalence of variances of the clinical groups of Experiment 2 was significant, adjusted ("adj.") and rounded degrees of freedom for the corresponding T tests are reported.

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Tables and Figures

Table 1

Demographic and clinical features of the participants entering Experiment 1

Variables	**Depressed (n = 43)**	**Alzheimer (n = 22)**	**Elderly (n = 24)**
Sex	21 male	12 male	9 male
Age	62.1 (6.6) 55–80	65.7 (6.1) 56–78	64.5 (8.3) 55–80
Education (years)	10.3 (2.8) 8–18	9.9 (2.3) 8–17	9.8 (2.1) 8–18
Beck depression inventory	19.8 (7.6) 11–41	5.8 (4.2) 0–17	5.4 (3.2) 0–10
Mini mental state (MMSE)	29.1 (0.8) 27–30	21.5 (3.3) 13–25	28.5 (1.3) 27–30
Appointments delayed	10.0 (6.2) 0–24	0.5 (0.7) 0–2	9.7 (4.8) 0–24

Measures of variability are given in parentheses (standard deviations and range)

Table 2

Summary of mean experimental test scores, standard deviation and range for participant groups in Experiment 1

Variables	**Depressed**	**Alzheimer**	**Elderly**
Digit span	4.9 (0.9) 3–8	4.3 (0.9) 2–6	5.0 (0.9) 3–6
Single task	95.1 (5.5) 80–100	90.1 (8.8) 71–100	95.3 (5.5) 84–100
Dual task	92.1 (5.9) 68–100	84.2 (12.6) 57–100	90.1 (8.2) 73–100
Tracking score			
Single task	221.1 (68.7) 55–350	145.1 (65.7) 37–291	246.0 (58.5) 154–329
Dual task	197.7 (73.4) 61–386	89.9 (50.5) 9–188	216.3 (57.7) 116–329
Dual task costs			
Tracking	88.1 (12.3) 65–110	63.2 (24.2) 21–91	87.1 (14.1) 48–114
Memory	97.2 (6.4) 80–112	93.0 (10.8) 59–115	94.1 (6.7) 81–106

Fig. 1.

A Scatterplot of individual overall percentage dual-task costs for healthy elderly controls, depressed, and Alzheimer disease patients in Experiment 1. Negative scores indicate better performance under dual-task conditions compared with single task

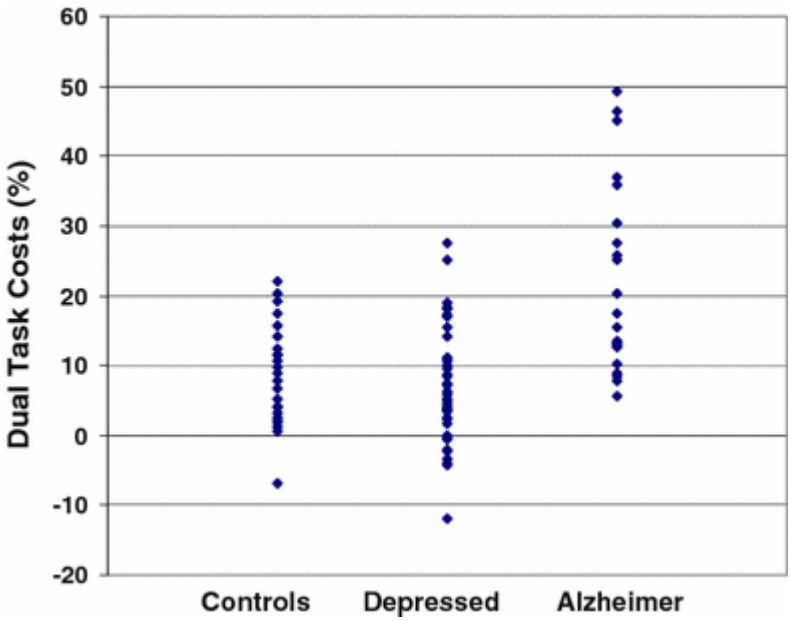

Fig. 2.

A ROC-curve depicting sensitivity and specificity of the combined dual task measure (i.e., tracking and memory list) used in Experiment 1. This curve compares the AD (Alzheimer disease) group using the healthy control group as reference (higher sensitivity scores indicate elevated costs). b. ROC-curve depicting sensitivity and specificity of the combined dual task measure (i.e., tracking and memory list) used in Experiment 1. This curve compares the AD (Alzheimer disease) group using the group of depressive patients as reference (higher sensitivity scores indicate elevated costs). c. ROC-curve depicting sensitivity and specificity of the combined dual task measure (i.e., tracking and memory list) used in Experiment 1. This curve compares the depressive patients using healthy controls as the reference group (higher sensitivity scores indicate elevated costs)