No dual-task practice effect in Alzheimer's disease

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Abstract

Diagnosis of Alzheimer's disease (AD) requires evidence of progressive decline in cognitive function. However, many tests used to assess cognitive function suffer from considerable practice effects, reducing their reliability. Several studies have reported that the ability to do two things at once, or dual tasking, is impaired in AD, but unaffected by healthy ageing. The apparent specificity of this impairment suggests that this assessment may be particularly useful in the early diagnosis of AD, but the reliability of this assessment remains unknown. Therefore, this study investigated simultaneous performance of digit recall and tracking tasks across six testing sessions, in eight people with AD, eight healthy older adults and eight healthy younger adults. The results found that dual task performance was unaffected by healthy ageing, but significantly impaired in AD, with no effect of repeated exposure. The absence of any improvements in performance despite increased familiarity with the task's demands suggests that not only is the dual task assessment well suited for monitoring progression over time, but also that dual tasking involves a specific cognitive function which is impaired in the AD brain.

Keywords

Alzheimer's disease

Dual task

Practice

Reliability

Assessment

Introduction

The ability to perform two tasks at the same time, or 'dual task', is unaffected by healthy ageing (Anderson, Bucks, Bayliss & Della Sala, 2011; Baddeley, Logie, Bressi, Della Sala & Spinnler, 1986; Belleville, Rouleau & Caza, 1998; Della Sala, Foley, Beschin, Allerhand & Logie, 2010; Foley, Kaschel, Logie & Della Sala, 2011; Logie, Cocchini, Della Sala & Baddeley, 2004; MacPherson, Della Sala, Logie & Wilcock, 2007; Salthouse, Fristoe, Lineweaver & Coon, 1995), but significantly impaired in Alzheimer's disease (AD; Baddeley, Bressi, Della Sala, Logie & Spinnler, 1991; Baddeley et al., 1986; Della Sala, Baddeley, Papagno & Spinnler, 1995; Foley et al., 2011; Holtzer, Burright & Donovick, 2004; Logie et al., 2004; MacPherson, Della Sala, & Logie, 2004; MacPherson et al., 2007; Morris, 1986; Morris & Baddeley, 1988; Sebastian, Menor & Elosua, 2006; Della Sala et al., 2010; Cocchini, Logie, Della Sala, MacPherson & Baddeley, 2002), with increasing impairment observed as the disease progresses (Baddeley, Baddeley, Bucks & Wilcock, 2001; Baddeley et al., 1991; MacPherson, Parra, Moreno, Lopera & Della Sala, 2012).

This impairment has been replicated using several different task combinations, including verbal and visual memory tasks (e.g. MacPherson et al., 2007), memory and motor tasks (e.g. Foley et al., 2011) and everyday task combinations such as walking and talking (e.g. Cocchini, Della Sala, Logie, Pagani, Sacci & Spinnler, 2004). It appears that as long as the two tasks do not compete for the same cognitive resources, but rather involve sufficiently different processes that avoid input and output conflicts (such as aural presentation of verbal material for oral recall, and visual presentation of material for a manual response), healthy adults, but not people with AD, can perform the two tasks in parallel with minimal dual task decrement relative to single task performance (Baddeley et al., 1991; Baddeley et al., 1986; Cocchini et al., 2002; Della Sala et al., 1995; Della Sala et al., 2010; Green, Hodges, &

Baddeley, 1995; Hartley & Little, 1999; Logie et al., 2004). Dual tasking is also unaffected by other disorders that can mimic AD, such as chronic depression in old age (Kaschel, Logie, Kazén & Della Sala, 2010) and Mild Cognitive Impairment (Foley et al., 2011), suggesting that the dual task impairment is specific to AD.

It has been suggested that this specific impairment in AD may simply reflect reduced attentional resources in a damaged brain (Perry, Watson, & Hodges, 2000). However, when the dual task is performed at varying levels of demand, AD patients always display dual task impairment, even when the demands of each individual task are set at a very low level. Moreover, the AD patients do not show differential sensitivity to increased demands within a single task (Logie et al., 2004). Thus, the dual task impairment in AD cannot simply reflect the effect of overall cognitive demand, but rather the impairment of a specific coordination function. This coordination function has been considered as one of the executive functions (Baddeley & Della Sala, 1996; Logie et al., 2004), as defined within the multiple component model of working memory (Baddeley, 1996; Baddeley & Logie, 1999; Logie, 2011).

These findings suggest that dual task impairment is a specific marker of AD, and therefore may be a valuable resource in the early and accurate diagnosis of AD. Early and accurate diagnosis of AD is important for enabling people to access appropriate treatment and support options, and for identifying individuals suitable to participate in research trials of therapies that may become available. Currently, AD is diagnosed upon the presence of an impairment in episodic memory (e.g. Dubois et al., 2007), but episodic memory impairment is not specific to AD, and can occur in a number of disorders, such as chronic depression in old age (Gainotti & Marra, 1994; Kopelman, 1986; Williams, Watts, MacLeod, & Matthews, 1997), and even in normal ageing (for reviews see Balota, Dolan & Duchek, 2000, and Prull, Gabrieli & Bunge, 2000), leading to diagnostic uncertainty. However, before the dual task assessment can be used to aid clinical diagnosis, it is important to ensure it has sufficiently high reliability.

Clinical diagnosis of AD requires longitudinal follow-up to determine decline in cognitive function over time. Tests of cognitive function are commonly repeated to aid this diagnosis, quantify change in ability over time, or determine the effects of any clinical interventions. Such repeated assessment assumes that these tests have sufficiently high test-retest reliability (Lowe & Rabbitt, 1998), but many tests of cognitive function suffer from significant practice effects, where performance improves with repeated testing (Benedict & Zgaljiardic, 1998; Collie, Maruff, Darby, & McStephen, 2003; McCaffrey, Ortega, Orsillo, Nelles, & Haase, 1992; McCaffrey & Westervelt, 1995; Rapport, Brooke-Brines, Axelrod, & Theisen, 1997). Practice effects are thought to be greatest in tests that have speeded responses, infrequently practised responses, or easily conceptualised solutions (Rapport et al., 1997). Such improvements may reflect memory of the correct answer, particularly if there is only one possible solution, or memory of a specific strategy used to perform the task (Rapport et al., 1997). Accordingly, practice effects are often greatest between the first and second assessment sessions (Collie et al., 2003; Rapport et al., 1997), on tests of executive function (Collie et al., 2003), and in neurologically intact (Shatz, 1981), younger people (Hornton, 1992; Ryan, Paolo, & Brundgardt, 1992; Salthouse, 2010), with higher IQs (Collie et al., 2003; Rapport et al., 1997; Salthouse & Tucker-Drob, 2008). Improvements as a result of practice can also occur as a result of repeating a test even after a gap of several years (e.g. Rabbitt, Diggle, Holland, & McInnes, 2004). These practice effects make it extremely difficult to know if an improvement in performance between testing sessions reflects genuine restitution of function or the effects of a specific intervention, such as active medication, or simply prior exposure.

Further difficulties in the interpretation of performance improvements arise from the possibility of increased “test sophistication” (Anastasi, 1981), where performance improves with increased test familiarity and/or adoption of strategies and decreased test-anxiety, leading to false impressions of change in underlying cognitive function (Hausknecht, Hapert, Di Paolo & Moriarty Gerrard, 2007). Performance on repeated testing may also change because of changes in measurement or random error. For example, test performance has been found to change over time simply because people change the strategy that they use to perform the test (Johnson, Logie & Brockmole, 2010; Logie, Della Sala, Laiacona, Chalmers, & Wynn, 1996), or because of statistical regression to the mean (Barnett, van der Pols, & Dobson, 2005; Nesselroade, Stigler, & Baltes, 1980). Such regression occurs when random error in test performance becomes averaged across testing sessions, so that with repeated testing lower scores appear to increase, and higher scores reduce, giving a false impression of real change.

Marked practice effects have been found in test batteries commonly used to assess AD, like the CANTAB (Lowe & Rabbitt, 1998), with many of the subtests having unacceptably low test-retest correlations (including all tests within the ‘Working Memory and Planning Battery’ component), and/or significantly large practice effects, with performance significantly improving upon repeated testing (such as the ‘Delayed Match to Sample’ subtests). Similarly, significant practice effects have been found on specific tests of episodic memory, including visual and verbal paired associates (Collie et al., 2003; Salthouse, Fristoe, & Rhee, 1996), visuo-spatial ability (Owen et al., 2010), and executive function (Basso, Bornstein, & Lang, 1999; Owen et al., 2010). Such practice effects can be substantial, leading to improvements of up to 0.40 standard deviation units or more (for meta-analyses see Hausknecht et al., 2007; Salthouse & Tucker-Drob, 2008). These tests are often used to aid diagnosis of AD, assess the impact of established and novel interventions, and monitor decline over time, but such practice effects obviously make it extremely difficult to have confidence in any conclusions that are drawn.

Initial investigations into the reliability of the assessment of dual tasking suggest that dual task performance is stable across two testing sessions. Della Sala et al. (2010) examined performance on two occasions, and found that the dual task measure gave a reliable index of dual tasking ability. However, a test-retest correlation coefficient can only give an analysis of similarity in score ranking across the two testing sessions, not a comparison of absolute scores, which, despite high test-retest reliability, may differ significantly (Rapport et al., 1997), and thus further evaluation of dual tasking ability over several sessions is required to explore the clinical utility of the dual task assessment.

The test-retest reliability of the dual task measure also has theoretical implications. If the dual task impairment demonstrated by people with AD was simply caused by cognitive overload, repeated exposure to the dual task should enable performance to become more automatic, leading to a decrease in cognitive demand, and improvement in dual task performance. However, if the dual task impairment is caused by a real impairment in a specific function, then dual task performance relative to single task performance should remain stable, irrespective of prior exposure to the test.

Thus, the aim of the current study was to explore the effect of practice on dual task performance in AD and normal ageing, in order to determine how repeated testing affects dual task performance, and how this differs, if at all in people with AD.

Methods

Participants

Twenty patients with probable AD were recruited, 11 of whom failed to meet our inclusion criteria. One patient was excluded because of deafness. Therefore, eight patients (four women and four men) completed the experimental conditions and were included in the final analysis. They had been diagnosed in accordance with the National Institute of Neurologic, Communicative Disorders and Stroke-AD and Related Disorders Association (NINCDS-ADRDA; McKhann et al., 1984) and DSM-IV (APA, 2000) criteria. Patients were only included if they showed unequivocal evidence of deterioration as determined by neurological and neuropsychological assessment over a period of at least 6 months, had a Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) score between 15 and 25 (mild/moderate clinical stage), were less than 85 years of age, performed normally on the first two sections of the Token Test (De Renzi & Faglioni, 1978) as a measure of verbal comprehension, and were willing to take part. The AD patients ranged in age between 70 and 77 years (mean = 74.10, SD = 2.40), and in formal education from nine to 12 years (mean = 10.00, SD = 1.40) and had a mean MMSE score of 21.10 (SD = 2.30, range 18 – 24).

The eight healthy older adults (four women and four men) were matched as closely as possible to the AD group for age, gender and education. All healthy older participants had no history of psychiatric, neurological or degenerative disorder, or brain injury. They had an age range of 64 to 80 years (mean = 72.25, SD = 6.40), and an education range of nine to 14 years (mean = 10.60, SD = 1.80). All of the healthy older adults scored above 25 on the MMSE (range 26 – 30, mean = 28.90, SD = 1.30).

The eight healthy younger adults (four women and four men) were also matched as closely as possible for gender and education. All healthy younger participants had no history of psychiatric or neurological disorder, or brain injury. They had an age range of 21 to 35 years (mean = 25.75, SD = 6.00), and an education range of 12 to 18 years (mean = 13.90, SD = 2.40).

Procedure

Each participant completed the dual task assessment, which consisted of performing a digit recall and computerised tracking task separately and then simultaneously. This assessment has been described previously (e.g. Baddeley et al., 1986; Cocchini et al., 2002; Logie et al., 2004; 2007).

Before commencing the digit recall task, digit span for each individual was established. Participants heard a list of digits at a rate of one per half-second. Participants were then asked to repeat these digits back in the same order as they heard them. The initial sequence length was two digits long and participants were presented with three sequences at each sequence length. If two out of the three sequences were recalled correctly, the digit sequence was lengthened by one digit. Once a participant could no longer recall two out of the three digit sequences, digit span was taken as the maximum length at which the participant was able to recall two out of three digit sequences correctly.

After the participant's span had been established, they heard sequences at their individual span length for immediate serial recall, and this was repeated for as many sequences as could be presented and recalled over a 90 second period. Sequences were never repeated. The number of sequences for each participant varied depending on the length of their digit span, and the performance measure was the proportion of digits accurately recalled in the correct serial order position. The first sequence was considered as a run-in and was discarded from the final analysis.

Before the tracking task was performed, tracking span for each individual was established. The tracking task consisted of using a light-sensitive stylus to follow a red oval with dark spots (resembling a ladybird, and measuring 2.5 cm long by 2 cm wide) moving around a computer monitor. The motion path of this target changed every five seconds, moving forward or turning left or right (turning up to a maximum of 45 degrees). Initially, the target speed was set at 4.5 cm per second (level 1) and if during the last five seconds the participant was in contact with the stimulus for over 60 % of the time, the speed was increased. In order to prevent fatigue, speed changed by one level (1 cm per second) when at slower speeds (levels 1 to 5), but changed by two levels (2 cm per second) when at faster speeds (levels 5 +). Once a participant could no longer remain on target for 60 % of the time, tracking span was taken at the highest speed at which the participant could remain 60 % on target. The computer screen was placed at an angle of 30 degrees from the horizontal, as this was found to be less physically tiring than attempting to track on a vertical screen (Baddeley et al., 1986; Logie et al., 2004).

After the participant's tracking span had been established, participants tracked the moving target for a further 90 seconds, with target speed kept constant and at span. The first 10 seconds were considered as a run-in and were discarded from the final analysis. The performance measure was percentage of time on target.

In the dual task condition, participants were asked to perform the tracking task at the same time as listening to and repeating back the digit sequences they heard, for a further 90 seconds. They were advised that they should attempt to do both tasks as well as possible. The first 10 seconds of the tracking task were considered as a run-in and were discarded from the final analysis. The performance measures were the proportion of digits accurately recalled in the correct serial order position and the percentage of time on target.

Proportional performance in digit recall (pd was calculated by measuring the change in digit recall between single ($d$single) and dual task ($d$dual) conditions, where d is the proportion of digits recalled accurately, and using:

$$p_{\mathrm{d}} = 100 - \left[\frac{(d_{\mathrm{single}} - d_{\mathrm{dual}}) \times 100}{d_{\mathrm{single}}}\right]$$

Proportional performance in tracking (pt) was calculated by measuring the change in tracking between single ($t$single) and dual task ($t$dual) conditions, where t is the percentage of time on target, and using:

$$p_{\mathrm{t}} = 100 - \left[\frac{(t_{\mathrm{single}} - t_{\mathrm{dual}}) \times 100}{t_{\mathrm{single}}}\right]$$

A combined measure of overall dual task performance (μ) was also calculated to account for any trade-off between tasks.

Proportional performance in both tasks overall (μ) was calculated by using:

$$\mu = \frac{p_d + p_t}{2}$$

Participants performed the dual task six times. They were allowed to rest for a few minutes between each dual task assessment or for as long as they considered to be enough time before the next one. The test instructions were repeated at the beginning of each new assessment. At the end of the sixth dual task, participants were asked to repeat the two single tasks again. The presentation of both the digit recall and tracking single tasks was counterbalanced across participants, but consistent within participants. Thus, several scores were calculated: digit and tracking span, single task performance at baseline, proportional dual task performance of digit recall, tracking and both tasks overall (using single task performance at baseline to calculate these proportional performance scores) for each of the six dual task assessments, and single task performance following practice.

Results

Participants

A one-way ANOVA revealed no significant difference in age between the AD and healthy older group ($F < 1$). However, a one-way ANOVA revealed a significant difference in number of years of education received between the three groups [F (2, 21) = 9.23, p < .005]. Post-hoc *t*-tests showed that, after Bonferroni correction, the younger adults had received significantly more education than either the older adults or patients (both $p < .05$), but with no difference between the older adults and patients. Therefore, for all subsequent analyses, education was considered as a potential covariate.

Digit and tracking spans

Mean digit and tracking spans for each participant group can be found in Table 1.

--Table 1 around here --

As seen in Table 1, one-way ANOVAs revealed no group differences in digit span ($F < 1$), but significant group differences in tracking span [F (2, 21) = 6.22, $p < .01$, $r = .47$]. Post-hoc *t*-tests revealed that, after Bonferroni correction, younger adults had significantly faster tracking spans than the AD group (both $p < .05$), with no statistically significant difference between the healthy younger and older groups, and older and AD groups. An analysis of covariance (ANCOVA) also revealed no effect of education [F (1, 20) < 1, $r = .12$].

Proportional digit recall performance

Proportional performance in digit recall (*p*d) in the six dual task assessments (labelled 1 to 6) for each participant group can be found in Table 2.

--Table 2 around here--

A 3 (group) x 6 (assessment) ANOVA showed a significant effect of group on proportional performance in digit recall [F (2, 21) = 6.19, $p < .01$, $r = .48$], with post-hoc *t*-tests revealing that, after Bonferroni correction, both healthy groups performed significantly better than the AD group (both $p < .05$), but with no difference between the healthy younger and older groups. There was no effect of repeated assessment [F (5, 105) < 1, $r = .09$], and no interaction between group and repeated assessment [F (10, 105) < 1, $r = .07$], suggesting no effect of practice. An ANCOVA revealed no effect of education [F (1, 20) < 1, $r = .12$].

Proportional tracking performance

Proportional performance in tracking (*p*t) in the six dual task assessments (labelled 1 to 6) for each participant group can be found in Table 3.

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A 3 (group) x 6 (assessment) ANOVA showed a significant effect of group on proportional performance in tracking [F (2, 21) = 13.74, $p < .001$, $r = .63$], with post-hoc *t*-tests revealing that, after Bonferroni correction, both healthy groups performed significantly better than the AD group (both $p < .05$), but with no difference between the healthy younger and older groups. There was neither an effect of assessment [F (5, 105) < 1, $r = .04$], nor an interaction between group and assessment [F (10, 105) < 1, $r = .05$], suggesting no effect of practice. An ANCOVA revealed no effect of education [F (1, 20) < 1, r = .08].

Overall dual task performance

Overall dual task performance (μ) in the six dual task assessments (labelled 1 to 6), for each participant group, can be found in Table 4.

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Once again, a 3 (group) x 6 (assessment) ANOVA showed a significant effect of group on overall dual task performance [F (2, 21) = 16.50, $p < .0001$, $r = .66$], with post-hoc *t*-tests revealing that, after Bonferroni correction, both the healthy younger and older groups performed significantly better than the AD group (both $p < .001$), but with no difference between the healthy younger and older groups. There was neither an effect of assessment [F (5, 105) < 1$, r = .06$], nor an interaction between group and assessment [F (10, 105) < 1, r = .05], suggesting no effect of practice. There was also no effect of education [F (1, 20) < 1, r = .07].

Thus, the results suggest that the ability to dual task is unaffected by healthy ageing, but significantly impaired in AD. This relative impairment does not appear to be ameliorated by practice, but rather reflects a stable deficit that is unaffected by repeated testing.

Merged sets

In order to explore further any evidence of an overall practice effect, the six dual task assessments were merged into two sets, with the first three assessments merged into the first set, and the last three assessments merged into the second set. It was hypothesised that merging performance may allow for the detection of any subtle change in dual task performance that may not be detectable when comparing performance between each individual session.

A 3 (group) x 2 (set) ANOVA revealed a significant effect of group on proportional performance of digit recall [F (2, 21) = 13.74, p< .01, r = .63]. Bonferroni-corrected post-hoc tests revealed that the healthy older groups performed significantly better than the AD group (both p< .05), but no significant differences in between the healthy younger and older groups, or younger and AD group. There was also no effect of set [F (1, 21) < 1, r = .09], nor an interaction between group and set [F (2, 21) < 1, r = .26]. Furthermore, an ANCOVA revealed no effect of education [F (1, 20) < 1, r = .08].

Similarly, there was a significant effect of group on proportional performance of tracking [F (2, 21) = 6.19, $p< .05$, r = .63]. Bonferroni-corrected post-hoc tests revealed that the healthy younger and older groups performed significantly better than the AD group (both $p< .05$), but with no significant difference in between the healthy younger and older groups. There was also no effect of set [F (1, 21) < 1, r = .04], nor an interaction between group and set [F (2, 21) < 1, r = .08]. Again, an ANCOVA revealed no effect of education [F (1, 20) < 1, r = .12].

There was also a significant effect of group on proportional performance on both tasks overall [F (2, 21) = 16.50, $p < .001$, r = .77]. Bonferroni-corrected post-hoc tests revealed that the healthy younger and older groups performing significantly better than the AD group (both $p < .05$), but with no significant difference in between the healthy younger and older groups. There was also no effect of set [F (1, 21) < 1, r = .01], nor an interaction between group and set [F (2, 21) < 1, r = .16]. Again, an ANCOVA revealed no effect of education [F (1, 20) < 1, r = .02].

Thus, further examination continues to indicate a significant effect of group on dual task performance, with the AD group always showing significant impairment in dual task performance. Despite merging individual sessions into two sets, there remains no significant effect of repeated testing on proportional digit recall, tracking or overall dual task performance.

Single task performance before and after repeated testing

The final analysis compared performance on the two single tasks before and after the six assessments. It was hypothesised that, if there was any effect of practice, performance on these individual tasks should benefit from repeated testing. Pre- and post-practice performance on digit recall and tracking can be seen in Figures 1 and 2, respectively.

--Figure 1 around here--

However, a 3 (group) x 2 (condition) ANOVA revealed no significant effect of group [F (2, 21) = 2.27, r = .31], practice [F (1, 21) < 1, r = .20], or interaction between group and practice on digit recall performance [F (2, 21) < 1, r = .16]. An ANCOVA also revealed no effect of education [F (1, 20) < 1, r = .18].

--Figure 2 around here--

Although a 3 (group) x 2 (condition) ANOVA showed a significant effect of practice in tracking performance [F (1, 21) = 5.03, p< .05, r = .44], with tracking performance significantly improving with practice, there was no effect of group [F (2, 21) = 1.95, r = .29], and no interaction between group and condition [F (2, 21) < 1, r = .12]. An ANCOVA also revealed no effect of education [F (1, 20) < 1, r = .18].

Thus, repeated exposure appears to benefit performance on the motor-based measure of tracking, but not the verbal task of digit recall. This effect of practice is not affected by group, but rather all participant groups show similar improvement on the motor task.

Discussion

The major aim of the current study was to determine if there was an effect of practice on dual task performance in AD and normal ageing. As described previously (e.g. Logie et al., 2004), the dual task calibration procedure used in this study ensures that each of the individual tasks is titrated to each participant's individual ability on each test session, thus standardising the level of demand of the dual task assessment across individuals. Salthouse, Rogan and Prill (1984) argued that if individuals show slight performance differences on tasks performed as single tasks, they will almost certainly differ when they have to perform two tasks concurrently. By titrating tasks for individual ability levels, all three groups were performing at their own limits of ability under single task conditions. Any changes in performance between single and dual task conditions for any of the groups can then be attributed specifically to the demands of performing two tasks concurrently rather than reflecting differences between groups in their ability for single task performance on each of the two component tasks. This allows dual task performance to be compared directly across different individuals and different groups of patients without the comparison being driven by differences in single task performance across groups. The findings of the current study show that, when this calibration procedure is used, and when the dual task involves two tasks that load upon separate cognitive resources, dual tasking ability is unaffected by healthy ageing, but significantly impaired in AD. This is in line with previous studies showing that dual task impairment is a specific marker of AD (Baddeley et al., 1991; Baddeley et al., 1986; Della Sala et al., 1995; Foley et al., 2011; Holtzer et al., 2004; Kaschel et al., 2009; Logie et al., 2004; MacPherson et al., 2004; MacPherson et al., 2007; Morris, 1986; Morris & Baddeley, 1988; Sebastian et al., 2006).

The results also showed that whereas performance on the single task of motor tracking benefits from repeated practice, dual task performance of tracking, digit recall or both tasks simultaneously, is unaffected by repeated testing. In particular, there was no practice effect observed when assessments were compared either individually or when merged into earlier and later assessment sets. Indeed, there was negligible change in the absolute scores upon repeated testing. This finding reinforces the argument that measuring dual task relative to each individual's single task performance on each testing occasion avoids the effects of practice on dual task performance, even if there are changes in single task performance from one testing session to the next. This supports the findings of Della Sala et al. (2010), who reported a high test-retest correlation, when comparing dual task performance relative to single task performance across two testing sessions. The current study extends this finding, to confirm that in addition to similarity in score ranking, there is also no significant change in absolute scores, even when dual task is performed up to six times.

The presence of a practice effect in the tracking task when performed as a single task suggests that performance of the two individual tasks requires separate cognitive resources (which do benefit from increased task familiarity) from those required to perform the dual task (which do not). The presence of a practice effect on this tracking task is in line with previous research that suggests that practice effects are most commonly observed on speeded tasks (Rapport et al., 1997). However, any benefit of prior exposure dissipates when this task is performed simultaneously with another task, which suggests that dual task performance involves a different cognitive function from when performing either of the single tasks on their own.

Importantly, the absence of any practice effects across all three groups (n = 24), in the face of significant group differences in dual tasking ability between groups (n = 8), and significant test-retest differences in performance of the motor tracking task, suggests that small sample size could hardly account for the lack of a practice effect observed. Even before any conservative correction for multiple comparisons was applied, there was no evidence of any benefit from repeated practice across any of the three participant groups in dual task performance. However, it would of course be prudent to repeat this study with larger sample sizes, in order to confirm the absence of any significant effect of practice.

The absence of a practice effect also suggests that the dual task impairment observed in AD cannot simply be attributed to cognitive overload. Importantly, there was no benefit observed with repeated exposure and no development of performance automaticity, but rather evidence of a stable impairment in dual task performance. Thus, the current findings suggest that the dual task impairment reflects a specific deficit in the coordination of the performance of two individual tasks in the AD brain.

This coordination function has been considered as one of the executive functions (Baddeley & Della Sala, 1996; Logie et al., 2004), as defined within the multiple component model of working memory (Baddeley, 1996; Baddeley & Logie, 1999; Logie, 2011). Further study of how this putative coordination executive function deteriorates in comparison with other named executive abilities, such as the inhibition of pre-potent responses and shifting between cognitive sets, and other cognitive functions, such as episodic memory, would be important for revealing the cascade of cognitive impairment seen in ageing and with the onset of AD.

The lack of a practice effect also confirms the dual task measure as a reliable index of dual tasking ability. The lack of an effect of repeated testing distinguishes the dual task measure from many other commonly used assessments of cognitive functioning, such as the CANTAB or measures of episodic memory, which are prone to significant practice effects. Furthermore, as the demands of the two individual tasks are adjusted to individual level of ability, the dual task measure does not suffer from the floor effects commonly found in measures of episodic memory (e.g. Greene, Baddeley, & Hodges, 1996). Thus, the dual task assessment appears to be of particular value for clinical practice, for aiding the early and accurate diagnosis of AD, for monitoring cognitive performance over time, as well as identifying individuals suitable for clinical interventions and research trials.

In sum, therefore, the dual task measure appears to give a reliable index of dual tasking ability, which in turn seems to reflect a specific coordination function which is unaffected by healthy ageing but significantly impaired in AD.

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Tables and Figures

Table 1

Digit and tracking spans for each participant group

	Healthy younger Mean (SD)	Healthy older Mean (SD)	AD Mean (SD)
Digit span	6.70 (1.40)	6.60 (0.70)	6.20 (1.20)
Tracking span	17.70 (2.10)	14.00 (3.20)	12.50 (3.70)

Table 2

Proportional performance in digit recall for each participant group

Assessment	Healthy younger Mean (SD)	Healthy older Mean (SD)	AD Mean (SD)
1	89.83 (9.42)	88.15 (11.37)	73.66 (9.87)
2	88.96 (8.68)	88.11 (5.42)	74.75 (11.77)
3	89.81 (8.64)	89.70 (11.46)	75.21 (11.27)
4	85.09 (13.02)	94.28 (6.11)	74.90 (13.71)
5	88.98 (8.17)	83.68 (13.29)	72.61 (19.38)
6	90.54 (8.57)	88.81 (14.65)	76.84 (13.68)

Table 3

Proportional performance in tracking for each participant group

Assessment	Healthy younger Mean (SD)	Healthy older Mean (SD)	AD Mean (SD)
1	55.47 (6.07)	45.27 (10.74)	35.69 (8.18)
2	55.57 (7.03)	49.79 (10.01)	34.44 (11.40)
3	54.15 (8.43)	46.07 (9.59)	31.13 (11.89)
4	54.70 (6.44)	48.51 (10.60)	31.60 (10.29)
5	57.08 (7.19)	48.58 (11.69)	30.45 (8.70)
6	55.85 (8.00)	48.30 (10.86)	35.14 (10.60)

Table 4

Overall dual task performance for each participant group

Assessment	Healthy younger Mean (SD)	Healthy older Mean (SD)	AD Mean (SD)
1	97.99 (6.71)	89.67 (7.48)	79.69 (9.93)
2	97.79 (8.73)	93.93 (5.77)	79.16 (8.59)
3	96.81 (8.37)	91.34 (6.81)	76.36 (10.07)
4	94.56 (10.43)	96.14 (5.85)	75.98 (7.59)
5	99.00 (8.88)	90.09 (5.39)	74.12 (13.25)
6	98.90 (9.32)	92.81 (8.14)	80.54 (14.45)

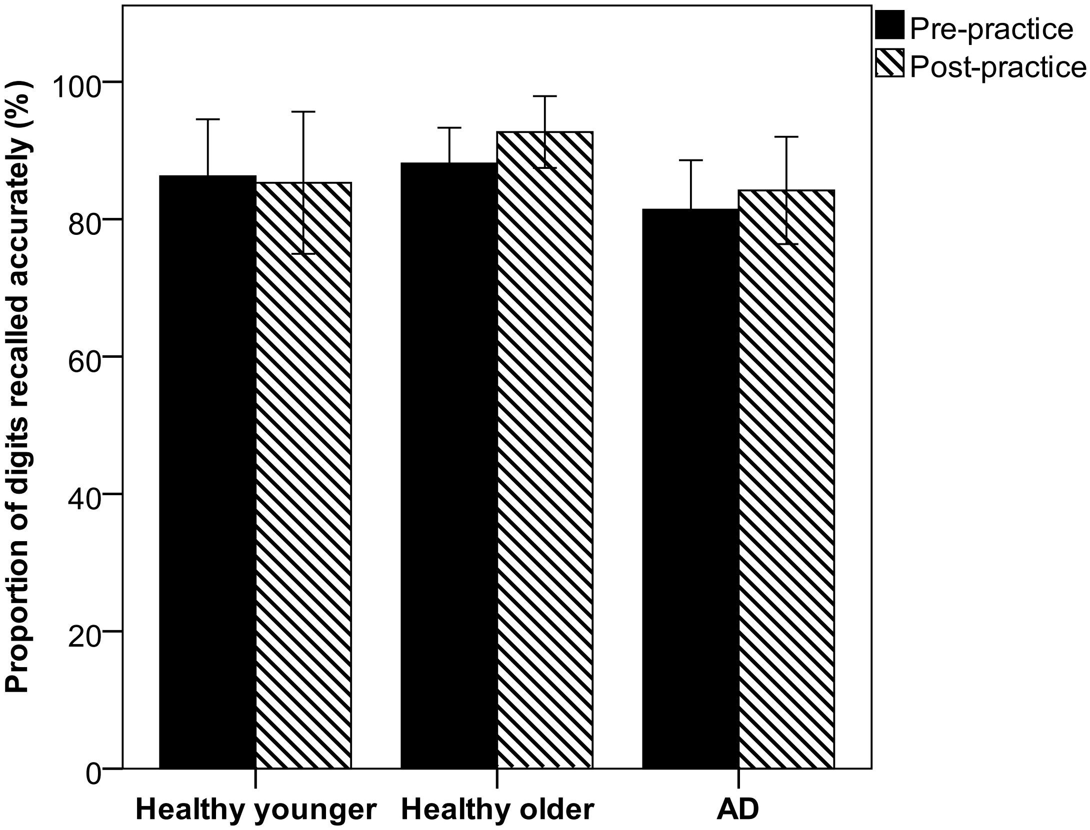

Figure 1: Pre- and post-practice single task performance of digit recall task in each participant group.

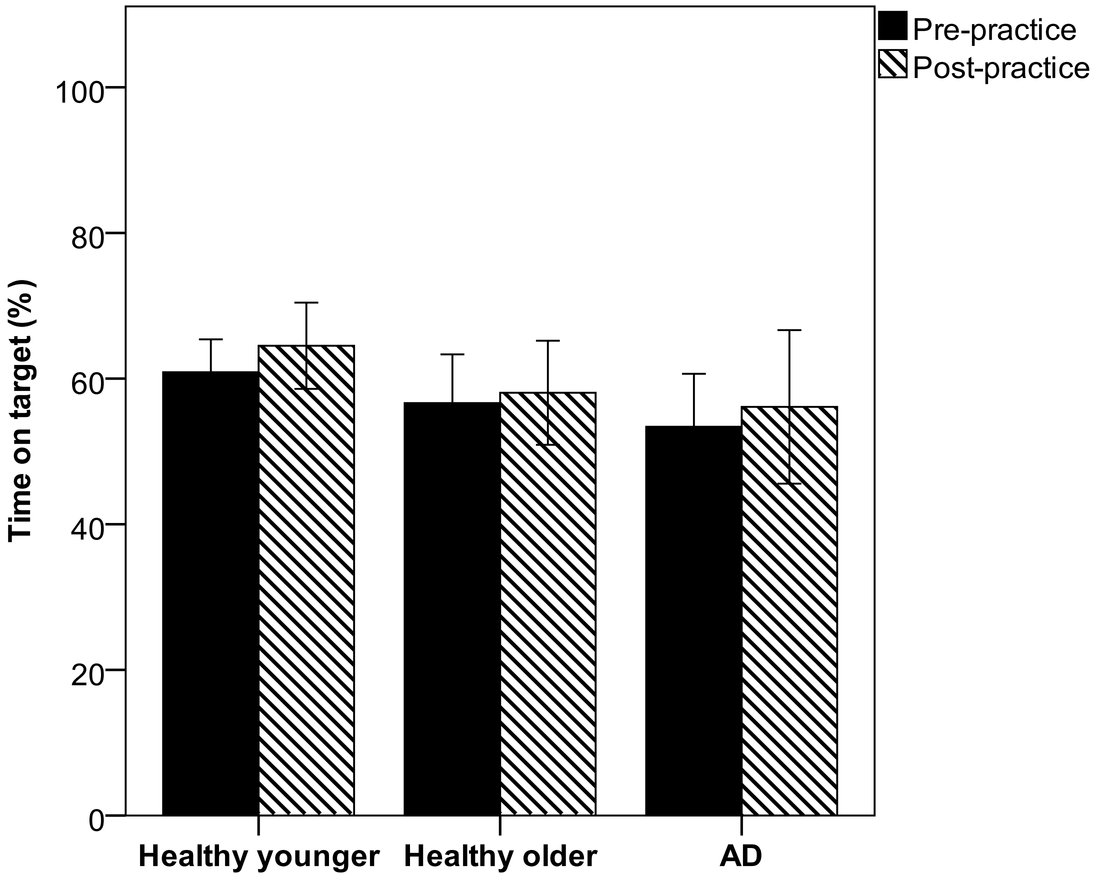

Figure 2: Pre- and post-practice single task performance of tracking task in each participant group.