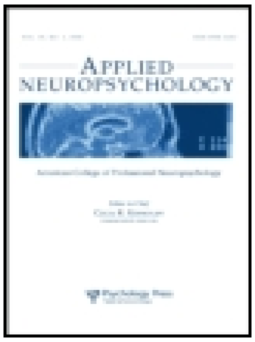

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Tracking Cognitive Functioning Over Time: Ten-Year Longitudinal Data From a Community-Based Study

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Over 10 years, a community-based sample age 65 ≥ years, with a starting cohort size of 1,206, was assessed biennially with the Mini-Mental State Exam; the Consortium to Establish a Registry for Alzheimer's Disease battery; Immediate and Delayed Recall of a Story; Verbal Fluency for P and S, Fruits and Animals; Clock Drawing; Temporal Orientation; and Trail Making tests. We report distributions of scores over time, at each wave, in (a) all individuals who were assessed at that wave, whether or not they participated in all waves, and (b) the Survivor subgroup of 425 participants who completed all tests at all 5 waves. Scores and factor structures remained remarkably stable over the study period. The most marked decline over time was seen on the Trail Making tests. As the survivors are de facto *a largely healthy and motivated group, their data can be considered population-based healthy norms and may serve as a reference for other studies conducting repeated evaluations using the same tests.*

Key words: cognitive function, neuropsychological tests, dementia screening, longitudinal study, assessment of change, aging

There is growing interest in the cognitive effects of normal aging and, especially in the clinical literature, in how normal age-related changes can be distinguished from early or incipient brain disease. Cross-sectional studies demonstrating differences in cognitive function between normal individuals and those diagnosed with mild cognitive impairment (Petersen et al., 1999) or frank dementia provide some information relevant to this issue. In practice, however, it is often helpful to confirm the suspicion of impairment by reexamining a potential patient after an interval with a view to documenting an abnormal degree of decline over time. Yet, interpreting what constitutes significant change can be difficult (Heaton et al., 2001). Abnormal decline can best be demonstrated by reference to longitudinal data, but the costs and other logistical difficulties of studying these phenomena

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longitudinally in a representative population are considerable. Consequently, longitudinal data for community-based populations are scarce. In particular, little information is available about the effects of repeat testing on cognitive test performance in representative samples of older individuals, even for well-standardized tests for which good cross-sectional norms are available.

In the course of conducting a prospective epidemiological study of dementia in a rural elderly community-based cohort over the previous 10 years, we screened our sample at approximately 2-year intervals. We used a battery of tests tapping a range of cognitive functions known to be affected by dementing disorders, primarily to identify individuals whose scores suggested the presence of cognitive impairment so that they could be further evaluated for the presence of dementia. A secondary purpose was to collect a body of population-based cognitive data for this population.

As with any other study in which repeated evaluations are planned, we had to decide whether to use the same test materials at each reevaluation or attempt to derive parallel forms. Neither approach is entirely satisfactory. Repeat testing, even at 2-year intervals, raises the possibility of practice effects that may vary from test to test and with the age or degree of impairment of the population (Chelune, Naugle, Luders, Sedlak, & Awad, 1993; Mitrushina & Satz, 1991). Memory tests using the same materials at each evaluation are particularly subject to practice effects (Chelune et al., 1993). The testing experience itself is probably a relatively unusual one for many normal elderly individuals, and it is known that reexposure to a distinctive setting facilitates memory for stimuli presented in that context in amnesic individuals (Winocur & Kinsbourne, 1978).

However, it is very difficult to equate multiple parallel forms adequately, and even if two forms of a test are equally difficult for normal individuals, there is no guarantee that they will be equally sensitive to pathology. Furthermore, it is impossible to prevent participants from learning from the experience of testing itself (e.g., that they may be asked to recall information after a delay) even when parallel forms are used.

Accordingly, we adopted the former approach and repeated the same test battery at each evaluation. In the process, we collected essentially normative longitudinal test data, which are reported here.

Methods

The Monongahela Valley Independent Elders Survey (MoVIES project) was a prospective community study from 1987 to 2002, set in the mid–Monongahela Valley of southwestern Pennsylvania, a rural non-farm community that has been in economic decline since the collapse of its steel industry in the late 1970s. The study's background and methods have been reported previously in greater detail (Ganguli et al., 1993; Ganguli, Ratcliff, & DeKosky, 1997; Ganguli et al., 1991; Ganguli, Seaberg, Ratcliff, Belle, & DeKosky, 1996). Briefly, the population reported here was selected by means of a 1:13 age-stratified (65–74, 75+), random sample of elderly individuals in 1987, identified through the voter registration lists for the target communities. Entry criteria included age 65 years or older, being community-dwelling (i.e., not in long-term care institutions) at the time of study entry, fluency in English, and at least a sixth-grade education. The last two conditions were designed to enhance interpretability of the neuropsychological tests.

After giving informed consent, participants were interviewed (the majority in their own homes) by trained research associates. The interview included, at each wave, 20 to 30 min of cognitive testing with a battery designed to tap a range of cognitive domains affected by dementia. At approximately 2-year intervals, surviving and consenting participants were invited to undergo cognitive testing again. Here we report data from five biennial data collection waves over 10 years, representing approximately 8 years of follow-up for each participant after initial cognitive testing at study entry.

The MoVIES cognitive screening battery included but was not limited to the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) neuropsychological panel (Morris et al., 1989). Included was a global cognitive measure (general mental status test), the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975). Orientation was assessed further by the Temporal Orientation Test. There were two tests of registration/learning and memory, from which four scores are reported here: immediate retell and delayed recall of an 18-item story (Becker, Boller, Saxton, & McGonigle-Gibson, 1987) as well as learning, and delayed recall of the 10-item CERAD Word List (Morris et al., 1989). Tests of language function included a confrontation naming test, the CERAD 15-item version (Morris et al., 1989) of the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) and 1-min Verbal Fluency tasks for initial letters (P and S) and for categories (Fruits and Animals; Lezak, 1995). Tests of praxis/visuospatial function included the Clock Drawing Test (Freedman et al., 1994) and the CERAD Constructional Praxis tasks (copying of four geometric shapes). Finally, the Trail Making Tests A and B (Reitan

& Wolfson, 1985) were included to assess executive functions, attention, set maintenance, and speed. We have previously (Ganguli et al., 1991) reported further descriptions of these tests, overall distributions of scores, and associations of scores with age, sex, and education level. We have also previously reported on the changes in scores over the first 2 years of follow-up, (Ganguli et al., 1996) and scores in demented and nondemented participants (Ganguli et al., 1997).

Participants

At baseline, 1422 randomly sampled individuals were screened by means of the previously mentioned cognitive tests. Participants identified as cognitively impaired were invited to undergo further clinical assessment to determine the presence or absence of dementia according to the *Diagnostic and Statistical Manual of Mental Disorders* (3rd ed., Rev. [*DSM-III–R*]; American Psychiatric Association, 1987) diagnostic criteria. During the baseline wave, 124 participants thus diagnosed as demented at study entry were classified as prevalent cases of dementia; a further 3 participants whose onset of dementia could not be determined and 87 participants who did not complete all the cognitive tests were excluded from this article. The remaining 1,208 individuals and their cognitive test data over five biennial waves were the participants of this study.

First, we report the distribution of scores of an inclusive group (i.e., all individuals who completed all the tests at each wave, whether or not they participated in the other waves). Attrition from this aging cohort among waves was primarily the result of mortality (9%–14% over all waves) and less so for reasons such as dropout and relocation (average, 2.8%). We also exclude from these analyses the individuals who participated in a given wave but completed only some of the tests examined here. The resulting sample sizes at Waves 1 through 5 are 1,208, 976, 800, 687, and 537, respectively. The remainder of the analyses to examine cognitive function and change longitudinally were carried out within the survivor subgroup of 425 participants who completed all tests at each wave.

As shown in the Results section, the survivor subgroup was significantly younger, better educated, and more likely to be female than the Inclusive group. By implication, the survivor subgroup was also healthier and possibly more motivated than the rest of the cohort because they survived and consented to participate in all waves. However, this is the only subgroup among whom it is possible to calculate longitudinal norms.

Statistical Procedures

Change in scores over time. In the two subgroups described previously (larger inclusive and smaller survivor groups), we examined mean and standard deviations on each test at each wave. For the survivor group, test scores were also disaggregated by age (< 75 years old, vs. ≥ 75), sex, and education (less than high school education vs high school and higher). We then compared mean scores on each test between the inclusive and survivor groups at both Wave 1 and Wave 5.

Next, among the survivor group ($n = 425$) which completed all 13 tests at all 5 waves, the statistical significance of changes between each successive wave and between Wave 1 and Wave 5 were examined by means of paired *t* tests. For the survivor group, we also calculated the mean and standard deviation of the decline in test scores between Wave 1 and Wave 5, and the proportion (%) of those who declined or improved at Wave 5 by more than 1 *SD* of the Wave 1 test scores. Finally, within the survivor group, on each test we examined whether changes between each successive wave and changes between Wave 1 and Wave 5 were associated with sex and education (less than high school education vs. high school and higher) in two age groups (< 75 years old vs. ≥ 75) separately, using analysis of variance.

Factor structure of the test battery over time. Within the survivor subgroup, we then performed exploratory factor analyses for those who completed all 13 tests at all 5 waves to determine the factor structure of the cognitive battery. We were able to normalize the highly skewed raw scores on Trail Making Tests A and B by transforming them to the square root of the number of correct connections per second. However, we had to exclude the Boston Naming Test, the Temporal Orientation Test, and MMSE from the factor analyses because of persistent ceiling effects. The remaining 10 tests were used for factor analysis.

Results

Sample Demographics

At Wave 1, the mean age of the inclusive group ($n = 1208$) was 72.9 ($SD = 5.6$), and of the survivor subgroup ($n = 425$) was 71.1 ($SD = 4.2$), a statistically significant difference ($p < .0001$ by Wilcoxon Rank–Sum test). The inclusive group was 55.5% female, whereas the survivor subgroup was 61.6% female ($p = .027$ by chi-square test); 57.4% of the inclusive group and 64.0% of the survivor subgroup had at least a high school education ($p = .017$ by chi-square test). Mean and standard deviations age of each group at each wave is shown in Table 1.

At Wave 1, mean scores on all tests were significantly higher in the survivor group than in the inclusive group ($p < .001$ by Wilcoxon Rank–Sum test), but at Wave 5, there were no significant differences in mean scores between the two groups on any test.

Table 1. *Cognitive Test Scores Over Time Among Survivor Subgroup[a] and Inclusive Group*

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
Test (Maximum Scores)	**a[b]**	**b[c]**	**a**	**b**	**a**	**b**	**a**	**b**	**a**	**b**
Number of participants	425	1208	425	976	425	800	425	687	425	537
M age	71.09	72.91	73.04	74.48	75.24	76.32	77.56	78.23	79.97	80.06
SD	4.24	5.58	4.25	5.25	4.23	4.88	4.23	4.62	4.20	4.16
MMTOT (30)										
M	28.19	27.66	27.70	27.19	27.54	27.14	27.48	27.10	27.21	27.07
SD	1.52	2.00	1.70	1.99	1.98	2.23	1.97	2.25	2.50	2.56
Story Immediate Recall (18)										
M	6.77	6.17	6.81	6.25	6.96	6.36	7.23	6.69	6.73	6.51
SD	3.03	2.95	2.73	2.80	2.81	2.88	3.19	3.25	3.11	3.09
Story Delayed Recall (18)										
M	6.14	5.42	6.28	5.55	6.31	5.66	6.31	5.81	6.01	5.73
SD	3.01	2.97	2.90	2.96	2.97	3.13	3.34	3.34	3.34	3.35
Word List, Learning (30)										
M	20.47	19.45	20.29	19.38	20.65	19.81	20.58	19.86	19.93	19.61
SD	3.59	3.70	3.50	3.70	3.51	3.80	3.86	4.08	4.32	4.36
Word List, Delayed Recall (10)										
M	6.94	6.36	6.96	6.49	7.09	6.63	6.90	6.45	6.50	6.32
SD	1.83	1.96	1.76	1.86	1.78	2.00	1.98	2.17	2.32	2.36
Boston Naming Test (15)										
M	14.42	14.21	14.38	14.16	14.31	14.14	14.28	14.16	14.16	14.16
SD	0.86	1.06	0.99	1.19	1.00	1.26	1.02	1.12	1.23	1.23
Verbal Fluency (n/a)										
Fruits and Animals										
M	28.22	26.69	27.80	26.44	27.29	26.12	26.64	25.76	25.52	25.37
SD	5.55	5.88	5.65	6.08	6.27	6.57	6.77	6.83	6.93	6.99
Letters P and S										
M	23.45	21.97	23.83	22.30	23.68	22.67	23.61	22.68	22.77	22.60
SD	7.21	7.44	7.47	7.37	7.18	7.39	7.89	7.97	8.18	7.98
Praxis (12)										
M	10.94	10.65	9.73	9.48	9.62	9.36	9.96	9.77	9.71	9.63
SD	1.15	1.29	1.22	1.38	1.24	1.33	1.17	1.27	1.29	1.32
Clock Drawing (8)										
M	7.55	7.43	7.38	7.21	7.25	7.09	7.20	7.08	6.94	6.90
SD	0.66	0.90	0.76	0.95	0.79	0.95	0.89	0.98	1.17	1.16
Trail Making A (300 sec)										
M	44.05	51.12	44.19	50.50	47.76	52.90	50.97	54.96	56.83	57.20
SD	14.69	23.56	15.01	22.82	16.81	24.08	20.23	25.94	29.17	29.05
Trail Making B (300 sec)										
M	111.70	136.49	122.81	144.46	130.99	150.94	143.46	158.32	165.84	168.72
SD	49.30	67.56	58.52	70.62	63.64	73.60	72.27	78.45	82.43	81.85
Temporal Orientation (n/a)										
(error scores)										
M	0.34	0.64	0.39	0.71	0.46	0.85	0.60	1.09	2.29	2.30
SD	1.31	3.86	0.96	3.83	1.30	3.98	2.22	5.60	9.92	10.21

Note: MMTOT = Mini-Mental State Examination Total Score.
[a]$N = 425$. [b]Survivor subgroup. [c]Inclusive group.

Changes in Test Scores Over Time

Table 1 also shows the means and standard deviations on each cognitive test at each wave for (a) the survivor subgroup ($n = 425$), and (b) the inclusive group with $n = 1208$ at Wave 1 and diminishing sample sizes over subsequent waves. We emphasize that the survivor subgroup is a subset of the inclusive group and not a separate group. In both groups, there was a modest decline in mean scores on each test over the 8 years of follow-up. More strikingly, standard deviations are larger at later waves for all tests, suggesting that the test performance of both groups becomes increasingly heterogeneous over time.

The results of additional analyses for the survivor group are discussed in the following paragraph.

Changes Among Waves

The changes in mean scores on all tests between Wave 4 and Wave 5 were statistically significant based on the paired t test (all of the p values < .001, except MMSE, $p = .012$; Word List Learning, Delayed Recall, $p < .009$; Boston Naming, $p < .019$). Changes between Wave 1 and Wave 5 were significant for all tests except Story Immediate and Delayed Recall (Word List Learning, $p = .005$, and all other tests, $p < .001$). All changes were in the direction of declining performance over time. Between Wave 1 and Wave 2, changes in MMSE ($p < .001$), Praxis ($p < .001$), Clock Drawing ($p < .001$) and Trails B ($p < .001$) were significant. Again, all significant changes were in the direction of poorer performance at Wave 2. Between Wave 2 and Wave 3, Word List Learning improved ($p = .013$), whereas Category Fluency ($p = .023$), Clock Drawing ($p = .009$), Trail Making A ($p < .001$), and Trail Making B ($p < .001$) declined significantly. Between Wave 3 and Wave 4, Story Immediate Recall ($p = .015$) and Praxis ($p < .001$) improved, whereas Word List Learning, Delayed Recall ($p = .009$), Category Fluency ($p = .006$), Praxis ($p < .001$), Trail Making A ($p < .001$), and Trail Making B ($p < .001$) declined.

Tables 2 to 5 show the mean and standard deviation of test scores at each wave disaggregated by age, sex, and education in the survivor subgroup. Between Waves 1 and 5, within the younger group, individuals with less than high school education declined significantly more than individuals with more education on Trail Making B ($p < .001$), Category Fluency ($p = .019$), and Initial Letter Fluency ($p = .035$). Within the older group, men declined significantly more than women on Trail Making B ($p = .005$), Word List Learning ($p < .037$), and Category Fluency ($p < .001$). There was a Sex × Education interaction on the MMSE such that older, more educated women declined less ($p = .037$).

Table 6 shows, for the survivor group, the amount of decline between Waves 1 and 5. More than one-third of participants showed decline of more than 1 *SD* of Wave 1 scores over 8 years of follow-up on the following tests: Clock Drawing (46.6%), Trail Making B (44.0%), CERAD Praxis (39.5%), and Trail Making A (35.1%).

Factor Structures

A 5-factor structure emerged in exploratory factor analyses; factor loadings based on Varimax rotation for Wave 1 through Wave 5 are presented in Table 7. The highest loadings (and the second highest loadings if two loadings were similar) are highlighted to clarify the factor structure.

Data from Wave 2 and Wave 3 show the following clear 5-factor structure pattern:

Factor I: Immediate and Delayed Recall of Story.
Factor. II: Learning and Delayed Recall of the Word List.
Factor III: Verbal Fluency for Initial Letters (P and S) and Verbal Fluency for Categories (Fruits and Animals).
Factor IV: Constructional Praxis and Clock Drawing.
Factor V: Trail Making Tests A and B.

In the later waves, Wave 4 and Wave 5, Trail Making B also starts to load together with Praxis and Clock Drawing on Factor IV, although it continues to load almost to the same extent on Factor V, together with Trail Making A.

Discussion

Several general trends emerge from these data. On several of the tests, there was a tendency for scores to remain fairly stable or, in some cases, to improve slightly over the first three to four waves, followed by a decline thereafter. Indeed, the interval between Wave 4 and Wave 5 was the only one over which a significant decline in mean score was observed for each test. The most likely explanation for this pattern would be a practice effect that initially counteracted the aging effect but, growing weaker with each successive reevaluation, was

Table 2. *Changes in Cognitive Test Scores Among Survivor Subgroup*[a]

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
Test (Maximum Scores)	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Number of participants	96.00	138.00	96.00	138.00	96.00	138.00	96.00	138.00	96.00	138.00
MMTOT (30)										
M	28.44	28.73	27.76	28.26	27.84	28.30	27.74	27.28	27.35	28.15
SD	1.28	1.25	1.67	1.26	1.71	1.38	1.58	1.52	2.19	2.14
Story Immediate Recall (18)										
M	6.55	8.03	6.76	7.75	6.64	8.28	7.17	8.68	6.66	8.14
SD	2.81	2.74	2.30	2.45	2.43	2.46	2.64	2.89	2.91	2.79
Story Delayed Recall (18)										
M	5.83	7.58	6.07	7.54	6.05	7.78	6.03	7.97	5.80	7.59
SD	2.69	2.78	2.46	2.71	2.47	2.65	2.94	3.09	3.12	2.88
Word List, Learning (30)										
M	20.29	21.89	20.14	21.55	21.05	21.83	20.72	22.00	20.60	21.15
SD	3.38	3.25	3.43	3.03	3.11	3.23	3.57	3.51	4.04	3.92
Word List, Delayed Recall (10)										
M	6.84	7.65	6.86	7.60	7.25	7.56	6.95	7.56	6.86	7.09
SD	1.77	1.57	1.82	1.43	1.65	1.59	1.79	1.88	2.02	2.22
Boston Naming Test (15)										
M	14.56	14.61	14.40	14.57	14.49	14.43	14.50	14.43	14.35	14.35
SD	0.77	0.71	1.24	0.76	0.85	0.99	0.81	0.92	1.17	1.12
Verbal Fluency (n/a)										
Fruits and Animals										
M	28.32	30.15	28.06	30.06	28.03	29.72	27.24	29.26	26.86	27.96
SD	5.74	5.35	5.72	5.45	6.36	6.17	6.82	6.82	6.78	6.62
Letters P and S										
M	24.57	25.37	24.89	26.06	24.86	26.01	25.05	25.80	24.79	24.93
SD	7.37	6.89	7.89	6.61	7.10	6.64	7.51	7.54	8.93	7.50
Praxis (12)										
M	11.33	11.01	10.07	9.93	9.99	9.86	10.39	10.12	10.16	9.96
SD	0.97	1.16	1.18	1.18	1.11	1.29	1.07	1.08	1.13	1.18
Clock Drawing (8)										
M	7.63	7.67	7.47	7.49	7.43	7.37	7.46	7.25	7.22	7.09
SD	0.57	0.54	0.72	0.64	0.75	0.65	0.75	0.85	1.13	0.83
Trail Making A (300 sec)										
M	43.24	39.44	42.35	38.93	43.44	41.20	46.99	43.86	53.19	47.90
SD	18.84	10.84	13.04	11.51	13.63	10.80	15.88	14.36	32.28	22.79
Trail Making B (300 sec)										
M	100.30	95.91	107.57	98.93	115.72	103.20	118.80	112.66	142.77	129.05
SD	44.59	39.79	40.30	41.91	49.93	44.30	50.48	51.06	70.61	65.05
Temporal Orientation (n/a) (error scores)										
M	0.18	0.51	0.45	0.30	0.43	0.39	0.69	0.57	1.70	2.43
SD	0.56	2.07	1.20	0.73	1.19	1.41	3.27	1.78	6.54	12.03

Note: MMTOT = Mini-Mental State Examination Total Score.
[a]*N* = 425. Age group: 65 to 74 years. Education: High School and higher.

finally overwhelmed by it. As might be expected, the practice effect seemed to be strongest for memory tests.

Exceptions to this pattern were Trails B, the only test on which mean score declined significantly at each wave, and, to a lesser extent, Trails A, Category Fluency, Constructional Praxis, and Clock Drawing. These were also the tests on which there was the greatest excess of declining over improving individuals between Waves 1 and 5, as shown in Table 6. The data for Praxis and Clock Drawing must be interpreted with caution, because these tests were subject to a ceiling effect that left more room for decline than for improvement. The consistent decline on the Trail Making Tests cannot be explained on this basis, and presumably indicates that these tests are less susceptible to practice effects, more sensitive to aging and its correlates, or both. Certainly, Trails B is known to be sensitive both to aging itself and to a number of age-related disorders (Elias, Robbins,

Table 3. *Changes in Cognitive Test Scores Among Survivor Subgroup*[a]

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
Test (Maximum Scores)	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Number of participants	7.00	31.00	7.00	31.00	7.00	31.00	7.00	31.00	7.00	31.00
MMTOT (30)										
M	28.57	28.10	27.57	27.94	27.00	27.87	26.71	27.71	25.71	27.58
SD	1.51	1.47	1.62	1.63	0.82	1.78	1.89	1.90	2.56	2.29
Story Immediate Recall (18)										
M	6.29	8.27	7.14	7.71	7.00	8.31	7.21	8.50	4.43	7.84
SD	3.05	3.21	2.34	2.57	2.75	2.90	3.04	3.34	1.72	3.91
Story Delayed Recall (18)										
M	5.29	7.34	7.36	7.37	5.86	7.60	6.14	7.44	3.86	7.21
SD	1.68	3.09	2.58	2.31	2.39	3.12	2.19	3.68	2.23	4.21
Word List, Learning (30)										
M	16.57	20.87	16.86	21.48	19.29	21.19	16.57	21.06	13.43	20.74
SD	1.90	3.83	2.73	4.16	3.55	3.94	2.37	3.93	4.69	4.23
Word List, Delayed Recall (10)										
M	6.00	6.90	6.29	7.00	5.86	7.29	5.86	7.19	4.57	6.45
SD	1.53	1.76	2.21	1.86	1.77	1.75	1.21	1.89	2.51	2.39
Boston Naming Test (15)										
M	14.14	14.42	14.57	14.42	14.14	14.32	14.14	14.16	13.71	14.10
SD	0.90	0.89	0.53	0.81	0.90	1.05	0.69	1.04	2.21	1.14
Verbal Fluency (n/a)										
Fruits and Animals										
M	27.14	28.35	26.57	28.13	26.86	27.84	26.14	28.55	18.86	26.45
SD	5.15	5.36	2.76	5.39	5.40	5.89	5.24	7.52	5.01	7.65
Letters P and S										
M	26.71	23.81	28.57	24.81	25.71	25.06	28.00	25.65	22.86	25.52
SD	5.35	5.75	5.06	6.94	6.26	7.94	6.35	10.02	8.73	9.00
Praxis (12)										
M	11.00	10.90	9.29	9.81	9.29	9.65	9.86	10.13	9.43	9.52
SD	1.41	1.14	1.11	1.14	1.80	1.02	1.35	1.31	1.40	1.09
Clock Drawing (8)										
M	7.86	7.48	7.00	7.35	7.29	7.10	7.14	6.97	6.43	6.74
SD	0.38	0.57	1.15	0.88	0.76	0.83	0.90	1.02	1.40	1.32
Trail Making A (300 sec)										
M	52.71	47.48	50.57	45.03	55.86	56.68	68.29	54.16	72.86	63.94
SD	20.77	12.76	19.31	13.10	23.53	20.49	24.07	19.14	25.78	34.11
Trail Making B (300 sec)										
M	108.71	117.84	121.86	129.23	115.29	142.45	152.57	158.26	261.14	184.71
SD	43.98	44.16	44.16	55.08	44.14	56.26	40.48	73.68	73.08	85.74
Temporal Orientation (n/a) (error scores)										
M	0.00	0.16	0.00	0.39	0.14	0.39	0.14	0.87	2.29	5.35
SD	0.00	0.45	0.00	0.67	0.38	0.62	0.38	2.28	4.42	15.93

Note: MMTOT = Mini-Mental State Examination Total Score.
[a]*N* = 425. Age group: 75+ years. Education: High School and higher.

Walter, & Schultz, 1993; Lafleche & Albert, 1995; Lezak, 1995; Reitan, 1958; Saxton et al., 2000; Spreen & Strauss, 1998), whereas category fluency tasks are differentially affected in Alzheimer's disease (Butters, Granholm, Salmon, Grant, & Wolfe, 1987; Martin & Fedio, 1983). Both the Trail Making and Fluency tasks emphasize processing speed, which has been implicated in age-related cognitive decline (Salthouse, 1996; Salthouse & Friscoe, 1995). In addition, Trails B requires that subjects monitor two sets of information simultaneously, thereby increasing the load on working memory, another cognitive domain that has been cited as a potential locus of the underlying decline affecting cognitive performance in the elderly (Dobbs & Rule, 1989; Wingfield, Stine, Lahar, & Aberdeen, 1988). Thus, the most consistent declines over time tended to occur on the tests that one might expect to be most sensitive to aging.

Table 4. *Changes in Cognitive Test Scores Among Survivor Subgroup*[a]

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
Test (Maximum Scores)	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Number of participants	42.00	72.00	42.00	72.00	42.00	72.00	42.00	72.00	42.00	72.00
MMTOT (30)										
M	26.95	28.04	26.69	27.79	26.31	27.25	26.45	27.24	26.05	27.07
SD	1.90	1.38	2.20	1.59	2.63	1.82	2.01	1.83	2.02	2.28
Story Immediate Recall (18)										
M	4.56	6.46	5.15	6.76	4.64	6.62	4.75	6.94	4.79	6.20
SD	1.84	3.08	2.74	2.78	2.45	2.71	2.65	2.82	2.26	2.74
Story Delayed Recall (18)										
M	4.06	5.72	4.05	6.06	4.23	5.87	3.73	6.05	3.71	5.69
SD	2.23	3.02	2.57	2.88	2.47	2.73	2.91	2.68	2.57	2.84
Word List, Learning (30)										
M	18.81	20.60	18.36	20.36	18.86	20.07	18.17	20.67	17.86	20.08
SD	3.47	3.46	2.70	3.37	3.29	3.54	2.90	4.09	3.56	4.41
Word List, Delayed Recall (10)										
M	6.10	7.01	6.19	6.93	6.48	6.89	6.12	6.74	5.69	6.43
SD	1.81	1.94	1.71	1.67	2.06	1.80	1.74	1.98	2.18	2.33
Boston Naming Test (15)										
M	14.31	14.18	14.40	14.28	14.33	14.11	14.33	14.22	14.19	13.93
SD	0.81	0.95	0.86	0.83	0.90	1.06	0.72	1.09	0.99	1.27
Verbal Fluency (n/a)										
Fruits and Animals										
M	26.88	26.43	25.48	26.26	25.40	25.07	25.33	23.85	22.79	23.78
SD	4.82	5.14	5.38	4.90	6.23	4.92	5.29	4.68	6.05	5.41
Letters P and S										
M	21.10	20.85	19.71	20.78	20.24	20.79	20.21	20.51	19.00	19.40
SD	7.37	6.67	6.77	6.72	6.24	6.20	6.56	6.41	6.87	6.11
Praxis (12)										
M	10.57	10.64	9.52	9.43	9.36	9.19	9.48	9.76	9.14	9.60
SD	1.33	1.07	1.25	1.07	1.48	0.94	1.15	1.11	1.54	1.23
Clock Drawing (8)										
M	7.57	7.46	7.38	7.24	7.10	7.18	7.21	7.14	6.79	6.94
SD	0.63	0.82	0.79	0.72	0.85	0.88	0.78	0.97	1.39	1.16
Trail Making A (300 sec)										
M	49.40	44.29	50.21	44.97	54.38	49.54	55.98	53.36	67.31	53.60
SD	13.99	12.20	17.28	12.62	17.95	15.27	15.91	18.37	29.09	18.59
Trail Making B (300 sec)										
M	133.05	124.32	147.50	141.42	163.29	142.94	172.29	165.32	201.98	183.97
SD	45.98	48.43	61.71	67.82	71.73	62.04	74.83	78.04	81.60	80.37
Temporal Orientation (n/a) (error scores)										
M	0.67	0.22	0.79	0.31	0.95	0.43	0.67	0.38	1.36	0.63
SD	1.26	0.48	1.52	0.76	2.29	0.82	2.55	0.81	3.92	1.30

Note: MMTOT = Mini-Mental State Examination Total Score.
[a]*N* = 425. Age group: 65 to 74 years. Education: Less than high school.

A practical implication for studies in which repeat evaluations are to be conducted would be that a modest decline over time is to be expected on some tests and is not necessarily abnormal. It is particularly important to appreciate this in the case of a test such as Trails B, which is known to be sensitive to incipient dementia and on which an abnormally large decline may be an important indicator (Rasmusson, Zonderman, Kawas, & Resnick, 1998). By contrast, even a small decline on a repeated memory test may be significant. Our data can serve as a basis on which to judge the amount of change to be expected on different tests.

The survivor group generally outperformed the inclusive group as would be expected on the assumption that the survivor group represents a healthy, motivated subgroup (Schaie, Labouvie, & Barrett, 1973; Siegler & Botwinick, 1979). Interestingly, this superiority was most evident in earlier waves and again seems to have

Table 5. *Changes in Cognitive Test Scores Among Survivor Subgroup*[a]

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
Test (Maximum Scores)	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Number of participants	18.00	21.00	18.00	21.00	18.00	21.00	18.00	21.00	18.00	21.00
MMTOT (30)										
M	26.78	27.71	26.56	26.19	24.94	26.48	24.78	26.19	24.94	25.05
SD	1.78	1.45	1.89	1.63	2.44	2.11	2.82	2.23	3.40	3.46
Story Immediate Recall (18)										
M	3.78	5.50	3.72	5.60	4.86	5.29	3.83	4.98	4.06	4.90
SD	2.54	2.57	2.05	3.25	2.72	2.09	3.23	2.97	3.11	2.56
Story Delayed Recall (18)										
M	3.14	4.88	3.22	4.88	3.56	4.21	3.11	4.00	3.03	3.83
SD	2.55	2.33	2.03	2.82	3.18	2.63	3.42	2.17	3.50	2.69
Word List, Learning (30)										
M	17.17	18.38	16.83	18.71	16.83	19.62	16.44	19.33	15.11	17.57
SD	3.03	3.02	3.19	3.21	2.07	3.57	3.50	3.06	3.38	3.16
Word List, Delayed Recall (10)										
M	5.28	6.05	5.56	6.24	5.28	6.86	4.83	6.14	4.50	5.29
SD	1.67	1.56	2.15	1.64	1.67	1.59	2.15	2.20	2.12	2.55
Boston Naming Test (15)										
M	14.17	13.90	13.89	13.62	13.61	13.86	13.28	13.48	13.28	13.76
SD	1.04	1.26	1.32	1.40	1.20	1.28	1.41	1.60	1.81	1.18
Verbal Fluency (n/a)										
Fruits and Animals										
M	27.17	24.90	24.72	24.19	22.56	22.71	19.56	22.38	18.72	21.57
SD	5.67	5.24	4.78	5.43	5.31	4.48	4.54	6.01	6.23	6.52
Letters P and S										
M	20.67	20.10	20.17	23.10	18.56	21.38	17.33	21.00	17.89	18.62
SD	7.10	7.67	6.97	9.11	4.96	8.59	5.25	9.28	5.86	8.83
Praxis (12)										
M	10.78	10.52	9.22	8.81	8.78	9.14	9.00	9.19	9.22	8.43
SD	1.06	1.25	1.35	1.36	1.11	1.15	0.97	1.12	0.81	1.57
Clock Drawing (8)										
M	7.44	6.81	7.22	6.95	7.17	6.52	6.94	6.43	6.28	5.90
SD	0.78	0.75	0.94	0.97	0.79	0.93	1.00	0.93	1.56	1.41
Trail Making A (300 sec)										
M	55.44	48.71	63.61	52.33	67.22	58.76	74.00	67.48	91.78	76.57
SD	15.77	13.29	25.93	15.23	27.60	16.59	27.93	39.75	34.86	32.22
Trail Making B (300 sec)										
M	139.33	149.86	178.39	179.43	202.06	205.29	235.94	221.91	255.33	242.24
SD	61.03	75.82	66.18	77.88	83.76	72.71	81.93	76.64	68.86	72.45
Temporal Orientation (n/a) (error scores)										
M	0.28	0.05	0.17	0.52	0.61	0.24	0.22	1.19	4.17	5.52
SD	0.57	0.22	0.38	0.81	1.04	0.54	0.55	2.66	14.73	15.54

Note: MMTOT = Mini-Mental State Examination Total Score.
[a]*N* = 425. Age group: 75+ years. Education: Less than high school.

been greatest for the Trail Making tests. Trails B performance more than a year prior to clinical onset is known to be predictive of future dementia (Chen et al., 2001). Possibly, some inclusive group members at Wave 1 were already exhibiting incipient cognitive decline that subsequently progressed sufficiently to cause their exclusion from later waves because of death or drop out. However, it should also be noted that the survivor subgroup formed an increasingly large subset of the inclusive group as the study progressed, constituting a substantial majority by Wave 5. The larger standard deviations in the inclusive group are also suggestive of greater heterogeneity in this group, just as the increasing standard deviations at successive waves reflect greater variability between subjects with increasing age, possibly because of an increased prevalence of health problems that may affect cognitive function (Elias, Elias, & Elias, 1990; Zelinski, Crimmins, Reynolds, & Seeman, 1998).

Table 6. *Amount of Decline Between Wave 1 and Wave 5 Among the Survivor Subgroup*[a]

Test (Maximum Scores)	Wave 1	Wave 5	Decline 1–5	Percentage Declined/ Improved More Than 1 *SD* of Baseline Scores at Time 5	
Number of participants	425.00	425.00			
MMTOT (30)					
M	28.19	27.21	0.98	D	31.3
SD	1.52	2.50	2.35	I	10.1
Story Immediate Recall (18)					
M	6.77	6.73	0.04	D	14.1
SD	3.03	3.11	2.81	I	10.1
Story Delayed Recall (18)					
M	6.14	6.01	0.13	D	13.2
SD	3.01	3.34	2.89	I	10.6
Word List, Learning (30)					
M	20.47	19.93	0.54	D	20.9
SD	3.59	4.32	3.94	I	13.9
Word List, Delayed Recall (10)					
M	6.94	6.50	0.44	D	1.4
SD	1.83	2.32	2.12	I	0.5
Boston Naming Test (15)					
M	14.42	14.16	0.26	D	28.5
SD	0.86	1.23	1.13	I	16.7
Verbal Fluency (n/a)					
Fruits and Animals					
M	28.22	25.52	2.69	D	30.1
SD	5.55	6.93	5.77	I	6.8
Letters P and S					
M	23.45	22.77	0.68	D	13.2
SD	7.21	8.18	6.67	I	12.2
Praxis (12)					
M	10.94	9.71	1.22	D	39.5
SD	1.15	1.29	1.40	I	2.1
Clock Drawing (8)					
M	7.55	6.94	0.62	D	46.6
SD	0.66	1.17	1.20	I	10.6
Trail Making A (300 sec)					
M	44.05	56.83	–12.79	D	35.1
SD	14.69	29.17	25.77	I	4.2
Trail Making B (300 sec)					
M	111.70	165.84	–54.14	D	44.0
SD	49.30	82.43	69.09	I	1.9
Temporal Orientation (n/a) (error scores)					
M	0.34	2.29	–1.96	D	11.1
SD	1.31	9.92	9.97	I	3.5

Note: MMTOT = Mini-Mental State Examination Total Score.
[a]*N* = 425.

Trails B is also something of an outlier in terms of the factor analysis. For the most part, the factor structure remained reasonably stable and easily interpretable over the five waves, with factors identified as narrative verbal recall (I), verbal list learning (II), verbal fluency (III), constructional/visuospatial ability (IV), and speed/executive functions (V). The relatively clear separation between Factor I and Factor II is a little surprising, but it is not unusual in the clinic to find quite marked dissociation between performance on narrative recall and list learning tasks. The fact that the Trail Making tests, especially Part B, began increasingly to load on the constructional/visuospatial factor at later waves would not have been predicted, but may be susceptible to post hoc explanation. Although the Trail Making tests stress speed of performance and

Table 7. *Exploratory Factor Analysis on Cognitive Test Battery Among Those Who Completed All 13 Tests at All Five Waves*[a]

	Wave 1					Wave 2					Wave 3					Wave 4					Wave 5				
Tests	**F1**	**F2**	**F3**	**F4**	**F5**	**F1**	**F2**	**F3**	**F4**	**F5**	**F1**	**F2**	**F3**	**F4**	**F5**	**F1**	**F2**	**F3**	**F4**	**F5**	**F1**	**F2**	**F3**	**F4**	**F5**
Story Immediate Recall	**0.88**	0.20	0.11	0.14	0.12	**0.94**	0.17	0.13	0.10	0.08	**0.90**	0.23	0.09	0.16	0.10	**0.81**	0.25	0.21	0.20	0.08	**0.86**	0.29	0.12	0.18	0.14
Story Delayed Recall	**0.95**	0.20	0.14	0.07	0.12	**0.85**	0.23	0.18	0.08	0.11	**0.89**	0.22	0.13	0.14	0.11	**0.93**	0.23	0.17	0.18	0.13	**0.86**	0.29	0.14	0.25	0.12
Word List Recall	0.15	**0.78**	0.16	0.09	0.13	0.23	**0.65**	0.23	0.12	0.12	0.17	**0.96**	0.15	0.15	0.12	0.28	**0.63**	0.27	0.19	0.14	0.28	**0.76**	0.17	0.18	0.17
Word List Delayed Recall	0.22	**0.85**	0.10	0.11	0.08	0.18	**0.97**	0.12	0.08	0.13	0.30	**0.66**	0.13	–0.01	0.14	0.23	**0.94**	0.17	0.16	0.10	0.28	**0.83**	0.13	0.21	0.12
Verbal Fluency Letters P and S	0.15	0.11	**0.42**	0.30	0.15	0.11	0.09	**0.60**	0.05	0.21	0.09	0.13	**0.83**	0.12	0.15	0.11	0.14	**0.64**	0.15	0.08	0.14	0.18	**0.95**	0.18	0.13
Verbal Fluency Fruits and Animals	0.10	0.16	**0.81**	0.08	0.21	0.17	0.23	**0.62**	0.12	0.22	0.18	0.28	**0.48**	0.20	0.35	0.22	0.19	**0.73**	0.21	0.16	0.31	0.31	**0.38**	0.34	0.28
Clock Drawing	0.04	0.10	0.08	**0.59**	0.04	0.06	0.06	0.06	**0.47**	0.14	0.07	0.06	0.00	**0.43**	0.16	0.14	0.16	0.11	**0.43**	0.03	0.13	0.12	0.07	**0.34**	0.13
Construction Praxis Total	0.12	0.01	0.09	**0.20**	**0.19**	0.05	0.06	0.05	**0.64**	0.06	0.08	0.02	0.13	**0.42**	0.11	0.07	0.04	0.10	**0.44**	0.16	0.09	0.08	0.08	**0.52**	0.11
Trail Making A	0.07	0.13	0.24	0.00	**0.57**	0.06	0.09	0.20	0.12	**0.70**	0.05	0.12	0.12	0.20	**0.69**	0.11	0.13	0.14	0.21	**0.95**	0.14	0.17	0.13	0.31	**0.92**
Trail Making B	0.11	0.09	0.07	0.17	**0.97**	0.13	0.16	0.29	0.23	**0.74**	0.16	0.12	0.25	0.36	**0.65**	0.19	0.17	0.31	**0.49**	**0.47**	0.24	0.24	0.25	**0.49**	**0.46**
Percentage Variance Explained			62.6					62.4					62.5					66.8					70.3		

[a]$N = 425$.

working memory, they also have a visuomotor component. If aging individuals develop increasing visuomotor problems or constructional deficits that begin to affect their performance on simple constructional tasks such as those used here, visuomotor/constructional ability might become a limiting factor on Trails. If so, Trails would increasingly come to load on the same factor as constructional tasks.

We show the data disaggregated by age, sex, and education show the effects of these variables and to provide a rough guide to the performance of the older persons or individuals with less than 12 years of education. Certainly these data should be interpreted with caution, because the age and education bands are quite broad and it is quite possible that individuals at the extremes of the education range within each education group differ substantially in cognitive test performance. However, the small numbers of participants at the post-baccalaureate and sixth-grade levels do not permit a finer-grain analysis. Within the limited range that we considered, we noted a tendency for more-educated individuals to decline less on some tests, as might be expected given the hypothesis that education protects against cognitive decline. The fact that this effect reached significance only in the younger subgroups may be related to the larger numbers in these groups or the possibility that, in the younger group, educational achievement may have been related more to ability than to opportunity, as compared to the older cohort.

The tendency for women to decline less than men on some tests in the older age group was less predictable. Women have been noted to outperform men on cognitive tests in some older samples (Saxton et al., 2000) including the MoVIES cohort (Ganguli et al., 1991), but one recent meta-analytic study of sex differences in aging found that most of the few Age × Sex interactions that reached significance indicated greater age-related decline in females (Meinz & Salthouse, 1998). There are, however, hints in the literature (Powell, 1994) that older, more-educated women may perform disproportionately well on cognitive tasks, possibly because women who received a college education in the early part of the 20th century may have constituted an unusually able and selected subgroup. Our finding of an Education × Sex interaction in the older subgroup on the MMSE is consistent with this, showing less decline in older, well-educated women.

In summary, we provide data relevant to the interpretation of the results of repeated cognitive testing in a large cohort of older, community-resident individuals. Performance remained relatively stable over time, with decline noted predominantly at later reevaluations. The most marked changes over time were seen on the Trail Making tests, which are known to be sensitive to both normal aging and age-related disease. Interpretation of changes over time must take into account the counteracting effects of practice and aging, the different rates of change associated with different tests, and their differential sensitivity to pathology.

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