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Journal
The Journals of Gerontology Series B, 50B(3)

ISSN
1079-5014

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Publication Date
1995-05-01

DOI
10.1093/geronb/50b.3.p171

Journal of Gerontology: PSYCHOLOGICAL SCIENCES
1995, Vol. 50B, No. 3, P171–P178

Age-Associated Changes in Specific Errors on the Benton Visual Retention Test

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While total errors on the Benton Visual Retention Test (BVRT) are known to increase in normal aging, there is little information on changes for specific error types. We examined the differential increase in seven specific error categories for 2,000 participants in the Baltimore Longitudinal Study of Aging. Cross-sectional analyses indicated that all errors increased with age, but differences between age groups in error profiles suggested relatively greater age effects for distortions, omissions, and rotations. There were also significant gender differences in error profiles, reflecting increased rotation and omission errors in females. Longitudinal analyses of age changes for a subset of 673 participants with three BVRT assessments were consistent with the cross-sectional data and indicated intra-individual increases with age in distortions, omissions, and rotations. While women made more omission errors, men showed steeper increases in omission errors with age. These findings suggest that cerebral aging impacts all categories of BVRT errors but has differential effects on particular error types.

CONVERGING evidence from cross-sectional and longitudinal studies indicates that performance on tests of visual memory declines with age, with accelerating change after age 70 (Arenberg, 1978, 1987; McCarty, Siegler, & Logue, 1982). Many studies have employed the Benton Visual Retention Test (BVRT), which involves immediate recall of designs and measures short-term visual memory, visual perception, and visual constructional abilities. For example, Arenberg (1978) studied BVRT performance in a large sample of participants in the Baltimore Longitudinal Study of Aging (BLSA). He demonstrated an increase in total errors among men aged 18 to 102 using three cross-sectional samples representing different cohorts and two longitudinal samples. The rate of decline was gradual at younger ages but was especially pronounced after age 70. These findings were extended to females in later studies (Giambra, Arenberg, Zonderman, Kawas, & Costa, 1995; Robertson-Tchabo & Arenberg, 1989).

Similar changes with age in BVRT performance were subsequently reported by other investigators. Benton, Eslinger, and Damasio (1981) found that the BVRT was sensitive to age differences in a sample of 34 men and 128 women aged 65 to 84, and Mormont (1984) observed age-related declines in 101 men aged 49 to 86. The increase in BVRT errors with age has also been demonstrated in a sample of elderly Japanese adults. Shichita, Shuichi, Ohashi, Shibata, and Matuzaki (1986) examined 5-year longitudinal changes in performance for 145 men and 157 women aged 69 to 71. Significant declines in BVRT performance were observed for both men and women. These investigators also noted that initial score, educational level, and activity were significant predictors of performance 5 years later. Although men performed better than women in this sample, gender did not significantly affect BVRT score after adjustment for education and activity.

While quantitative changes in total BVRT scores with age have been examined in a number of studies, age differences and longitudinal changes in qualitative error types have not been addressed. As described by Benton (1974), errors can be classified into a number of categories, including distortions, omissions, additions, misplacements, perseverations, rotations, and size errors. It has been argued that particular types of errors may be more sensitive to cerebral dysfunction. Pointrenaud and Barrere (1972) identified a number of specific errors which occur very infrequently in normal people, but were significantly more frequent in a heterogeneous group of patients with neurological disorders. Using a modification of the BVRT designed to promote perseveration errors, Vilkki (1989) demonstrated an increase in recurrent perseveration errors in patients with anterior frontal lobe lesions compared to patients with posterior lesions.

Studies of error types in patients with Alzheimer's disease (AD) have also indicated that particular errors may be differentially affected. In a series of 44 patients, Vollant, Lafitte, and Rapin (1986) reported that two types of omission and perseveration errors occurred in 40 to 50% of patients but were not found in healthy control subjects. Similarly, La Rue, D'Elia, Clark, Spar, and Jarvik (1986) found a selective increase in omission errors in patients with probable AD, and Eslinger, Pepin, and Benton (1988) observed increases in both omissions and perseverations among dementia patients.

Despite the evidence for differential increases of specific error types in a variety of disorders associated with cognitive dysfunction, there have been no reports describing age differences and longitudinal changes in specific error types in normal aging. The purpose of the present study is to examine whether particular types of errors contribute differentially to the increase in total BVRT errors observed with normal aging. Specifically, the following questions are addressed: (1) Do all error types increase with age? (2) Are the magnitudes of age differences and longitudinal changes similar for the different error types or categories? (3) Do men and women show similar patterns of errors and age differences and changes? We hypothesized that all types of errors would increase with age but that some would show relatively greater increases than others. In addition, we predicted that gender differences would be most likely to occur for rotational errors. Females were expected to make more rotation errors, based on gender differences in spatial rotational ability (Linn & Petersen, 1985).

METHOD

Subjects

The subjects were 2,000 participants in the Baltimore Longitudinal Study of Aging (BLSA), who had been administered the BVRT on at least one visit between 1960 and March of 1992. There were 1,365 men and 635 women ranging in age from 20 to 102 years. The distribution of subjects by age and gender is presented in Table 1. The BLSA participants are predominantly White, well-educated, and of higher than average socioeconomic status. They visit the Gerontology Research Center in Baltimore every 2 years for 2½ days of psychological and medical testing (Shock et al., 1984). More than 75% of men and 60% of women had at least a college education, with greater than 50% of men and 35% of women receiving some graduate education.

Of the 2,000 participants whose data were available for cross-sectional analysis, 692 had at least three BVRT assessments. Of the latter subjects, 19 received diagnoses of dementia and related disorders during the course of the study and were omitted from the longitudinal analyses. Thus, analysis of longitudinal change in specific BVRT errors was based on 673 normal, nondemented subjects with 3-point data. Average intervals between assessments were: (mean ± standard deviation) 7.15 ± 2.1 years between the first and second and 6.05 ± 2.0 years between the second and third assessments. Numbers of subjects by age at first test administration and gender are provided in Table 2. In this subsample, 82% of men and 69% of women had completed college, with 61% of men and 48% of women having some graduate education.

Procedures

The first BVRT administration was typically at the initial BLSA visit. For the first BVRT assessment, all participants were administered Form C. Forms E and D were employed for the second and third assessments, respectively. All forms were administered using Administration A, the standard procedure (Benton, 1974). Under the standard administration, a series of 10 designs is shown to the subject. Each design is displayed for 10 sec, withdrawn, and the subject then reproduces it from memory. Errors were scored according to standard procedures, as described in the test manual (Benton, 1974). All errors were classified into one of seven major categories: omissions, distortions, perseverations, rotations, misplacements, size, and addition errors. The classification of error types followed that detailed by Benton (1974) with one exception. Whereas Benton includes addition errors with omissions, we treated addition errors as a separate category. The sum of the individual errors for the 10 designs yields the total error score. All errors were scored independently by two experienced examiners, and disagreements were resolved by discussion. Previous research has indicated high to moderately high interrater agreement for the error subscores, ranging from kappa coefficients of .98 for omissions to .74 for size errors (Swan, Morrison, & Eslinger, 1990). Thus, our consensus procedure should yield highly accurate error subscores. Age differences and longitudinal changes in the total error scores have been reported for a subset of this sample by Arenberg (1978, 1987) and Robertson-Tchabo and Arenberg (1989).

As the Vocabulary subtest of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1955) was administered in parallel with the BVRT, Vocabulary scores were used to control for individual differences in general intellectual ability and possible cohort differences. Vocabulary scores were available for 1,990 subjects in the cross-sectional analyses and 671 in the longitudinal data set.

Data Analysis

Cross-sectional analysis of age differences. — Age differences in specific BVRT errors were investigated using two different approaches. Subjects were divided into 7 age groups: 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, and 80 and older (see Table 1). To compare the extent of age differences for the 7 error types, error scores were transformed to *z*-scores for each error type, using the mean and standard deviation across all ages. This transformation was necessary due to the differences in frequencies of the various error types. The second approach to analysis of the cross-sectional data involved repeated measures multivariate analysis of variance (MANOVA). This procedure was employed to examine differences in the profiles, as well as levels, of

Table 1. Distribution of BLSA Participants by Age Group and Gender: Cross-Sectional Analysis

Age Group	Men	Women	Combined
20–29	166	102	268
30–39	243	110	353
40–49	214	56	270
50–59	211	95	306
60–69	222	112	334
70–79	226	114	340
80 and older	83	46	129
Total	1365	635	2000

Table 2. Distribution of BLSA Participants by Age at First BVRT Administration and Gender: Longitudinal Analysis

Age Group	Men	Women	Combined
20–39	172	17	189
40–49	154	31	185
50–59	105	50	155
60–69	60	40	100
70 and older	21	23	44
Total	512	161	673

error scores across age and gender groups. The analysis was a 7 (Age Groups) × 2 (Gender) × 7 (Error Types) MANOVA. Age Group and Gender were grouping factors, and Error Type was treated as a repeated measures factor. In view of the large sample size, main effects and interactions were considered to be significant if they reached the .01 level. Significant interactions were decomposed using the BMDP4V "simple effects" procedure (BMDP Statistical Software, 1993). Effect sizes were estimated as partial eta squared (SPSS MANOVA, SPSS Inc., 1990) and indicate the magnitudes of the significant effects. Multivariate analyses were repeated, adding Vocabulary score as a covariate to control for possible cohort differences in general intellectual ability.

Longitudinal analysis of age changes. — Examination of longitudinal change in specific BVRT errors was based on 3-point data. For each subject, the slope of BVRT errors with age at testing was calculated separately for each error type, with each slope reflecting the magnitude of intra-individual age change for a specific error type. These yearly rates of change were then treated as "scores" in a MANOVA design analogous to that employed for analysis of the cross-sectional data. Subjects were divided into 5 age groups based on age at first testing. Due to relatively small samples in the youngest and oldest age groups, subjects ages 20–29 and 30–39 at first testing were collapsed into a single group, as were the two groups for subjects ages 70–79 and 80 and older. Thus, the MANOVA was a 5 (Age Groups) × 2 (Gender) × 7 (Error Types) design, with Age Group and Gender as grouping factors and Error Type as a repeated measures factor. An alpha of .01 was again adopted for significance of main effects and interactions, and effect sizes were estimated as described above. In addition, MANCOVA was performed on the slope scores, covarying for WAIS Vocabulary score at first testing. A limitation of the analysis of slope "scores" is the invalid assumption that errors increase linearly with age. Thus, the analyses were repeated using the individual test data for the three time points, adding time of testing as an additional repeated measures factor. As these analyses resulted in a similar pattern of findings and did not alter interpretations, analysis of the slope data is reported to facilitate the illustration of longitudinal change across error types.

To assess the potential impact of age-related declines in visual acuity on longitudinal change in BVRT errors, correlations were computed between change in visual acuity and change in BVRT error score. Visual acuity data collected at the same visit as the first two BVRT assessments were available for 190 participants, and acuity data collected concomitantly with the second and third assessments were available for 254 participants. Studies of visual acuity changes in the BLSA indicate that the majority of participants maintain acuity of 20/40 or better into their 80s (Gittings & Fozard, 1986).

RESULTS

Cross-sectional analysis. — Means and standard deviations for the 7 error types by age group and gender are presented in Table 3. As is apparent from the average error scores, there are differences in the overall frequencies of the specific error types. The mean *z*-transformed error scores for the 7 age groups are shown in Figure 1. All types of errors increase with age. To examine the relative magnitudes of age differences in the 7 error types, differences between the mean values of the *z*-transformed error scores for the "80 and older" and "20–29" age groups were calculated. The results indicated that the increase in errors with age was most pronounced for distortion and omission errors, 1.60 and 1.12, respectively. Differences for the remaining error types were: rotations, 0.98; size, 0.85; perseverations, 0.73; misplacements, 0.69; and additions, 0.61.

The results of the 7 (Age Groups) × 2 (Gender) × 7 (Error Types) MANOVA indicated a significant main effect for Age Group, but no significant effect of Gender or Age Group by Gender interaction. The highly significant main effect of age, $F(6,1986) = 139.09, p < .0001$ (effect size = .30), reflected a consistent increase in errors with age across all error types.

There was a highly significant effect of error type, $F(6,1981) = 802.41, p < .0001$ (effect size = .71), due to the differences in overall frequencies of the specific errors. There were also significant interactions between Error Type and Age Group, $F(36,8701.9) = 20.56, p < .0001$ (effect size = .06), and Error Type and Gender, $F(6,1981) = 3.86, p < .001$ (effect size = .01). The 3-way Error Type × Age Group × Gender interaction did not reach significance.

Decomposition of the significant Error Type × Age Group and Error Type × Gender interactions helped clarify the nature of the relationships with error profile. The significant interaction between Error Type and Age Group is illustrated in Figure 2. While main effects of age were highly significant for all error types ($p < .0001$), comparison of the error profiles across age groups suggests greater increases in distortions and omissions than in other errors with advancing age. Greater age differences for distortion and omission errors were also highlighted in our analyses of the *z*-transformed data described above. The age differences in error profiles were found for both men and women, as indicated by the absence of a significant Age Group × Gender interaction. In contrast, the significant interaction between Error Type and Gender indicates different error *profiles* for males and females for all age groups combined. The nature of this interaction is illustrated in Figure 3. Females make more omission, $F(1,1986) = 12.69, p < .001$ (effect size = .006), and rotational errors, $F(1,1986) = 5.31, p = .02$ (effect size = .003), but show similar performance to males with respect to the remaining error types.

MANCOVA, in which WAIS Vocabulary score was entered as a covariate to control for possible differences in general intelligence, yielded the same pattern of results.

Longitudinal analysis. — Results of the 5 (Age Groups) × 2 (Gender) × 7 (Error Types) MANOVA performed on the slope "scores" yielded a significant main effect of age group, $F(4,663) = 16.88, p < .0001$ (effect size = .09), reflecting increased intra-individual change with age for the older age groups. As shown in Figure 4, age changes did not reach significance until after age 50, with longitudinal

Table 3. Means and Standard Deviations for Specific Errors on First BVRT Administration by Age Group and Gender

Group	OM	ADD	DIS	PSV	ROT	MIS	SIZE
20–29							
Men	.02 ± 0.1	.00 ± 0.0	1.07 ± 1.0	.39 ± 0.7	.40 ± 0.7	.38 ± 0.7	.05 ± 0.2
Women	.04 ± 0.2	.01 ± 0.1	1.00 ± 1.2	.43 ± 0.7	.38 ± 0.6	.51 ± 0.8	.05 ± 0.3
Both	.03 ± 0.2	.00 ± 0.1	1.04 ± 1.1	.40 ± 0.7	.40 ± 0.6	.43 ± 0.7	.05 ± 0.2
30–39							
Men	.01 ± 0.1	.00 ± 0.1	1.07 ± 1.1	.53 ± 0.8	.53 ± 0.8	.47 ± 0.9	.06 ± 0.3
Women	.09 ± 0.4	.00 ± 0.0	1.26 ± 1.2	.43 ± 0.8	.65 ± 0.9	.39 ± 0.6	.02 ± 0.1
Both	.04 ± 0.2	.00 ± 0.1	1.13 ± 1.1	.50 ± 0.8	.57 ± 0.8	.45 ± 0.8	.05 ± 0.2
40–49							
Men	.07 ± 0.4	.00 ± 0.0	1.46 ± 1.3	.56 ± 0.7	.50 ± 0.7	.48 ± 0.7	.06 ± 0.3
Women	.09 ± 0.3	.00 ± 0.0	1.54 ± 1.3	.46 ± 0.7	.46 ± 0.7	.36 ± 0.7	.04 ± 0.2
Both	.07 ± 0.4	.00 ± 0.0	1.47 ± 1.3	.54 ± 0.7	.50 ± 0.7	.45 ± 0.7	.05 ± 0.3
50–59							
Men	.13 ± 0.5	.01 ± 0.1	1.73 ± 1.6	.64 ± 0.8	.64 ± 0.8	.63 ± 0.9	.08 ± 0.3
Women	.33 ± 0.8	.00 ± 0.0	1.98 ± 1.3	.71 ± 0.9	.76 ± 0.9	.52 ± 0.7	.06 ± 0.3
Both	.19 ± 0.6	.01 ± 0.1	1.81 ± 1.5	.66 ± 0.8	.68 ± 0.8	.59 ± 0.9	.07 ± 0.3
60–69							
Men	.21 ± 0.6	.01 ± 0.1	2.22 ± 1.6	.79 ± 1.0	.73 ± 0.9	.70 ± 0.9	.14 ± 0.4
Women	.54 ± 1.0	.00 ± 0.0	2.08 ± 1.4	.90 ± 1.1	1.01 ± 0.9	.56 ± 0.8	.12 ± 0.4
Both	.32 ± 0.8	.01 ± 0.1	2.17 ± 1.5	.83 ± 1.0	.83 ± 0.9	.66 ± 0.9	.13 ± 0.4
70–79							
Men	.54 ± 1.0	.02 ± 0.1	2.72 ± 1.8	1.14 ± 1.2	.91 ± 1.1	.79 ± 1.0	.19 ± 0.5
Women	.58 ± 1.5	.00 ± 0.0	2.57 ± 1.7	1.28 ± 1.2	1.21 ± 1.1	.88 ± 1.0	.16 ± 0.5
Both	.55 ± 1.2	.01 ± 0.1	2.67 ± 1.8	1.19 ± 1.2	1.01 ± 1.1	.82 ± 1.0	.18 ± 0.5
80–102							
Men	.82 ± 1.4	.05 ± 0.3	3.81 ± 2.4	1.00 ± 1.2	1.30 ± 1.0	1.05 ± 1.1	.39 ± 0.8
Women	1.09 ± 1.8	.11 ± 0.3	3.46 ± 1.9	1.33 ± 1.3	1.28 ± 1.0	1.00 ± 1.2	.39 ± 0.8
Both	.91 ± 1.6	.07 ± 0.3	3.68 ± 2.3	1.12 ± 1.3	1.29 ± 1.0	1.03 ± 1.1	.39 ± 0.8

Notes: OM = omissions; ADD = additions; DIS = distortions; PSV = perseverations; ROT = rotations; MIS = misplacements; SIZE = size errors.

change significant only for the three oldest age groups (all $p \leq .0001$). Effects of gender and the interaction between Age Group and Gender were not significant.

Consistent with the cross-sectional results, there was a highly significant effect of error type, $F(6,658) = 25.66$, $p < .0001$ (effect size = .19), indicating differences in the yearly rates of change for the specific error types (Figure 5). Significant intra-individual increases in errors with age were found for omissions, $F(1,663) = 7.40$, $p < .01$ (effect size = .01), distortions, $F(1,663) = 81.38$, $p < .0001$ (effect size .11), and rotations, $F(1,663) = 36.62$, $p < .0001$ (effect size = .05). Additions, perseverations, misplacement, and size errors did not show significant intra-individual change with age. There were significant interactions between Error Type and Age Group, $F(24,2296.7) = 4.87$, $p < .0001$ (effect size = .04), and Error Type and Gender, $F(6,658) = 4.61$, $p = .0001$ (effect size = .04), but the 3-way interaction between Error Type, Age Group, and Gender did not reach the .01 level of significance.

The interaction between Age Group, as defined by age at first testing, and Error Type is illustrated in Figure 6. Comparisons of error profiles for the different age groups indicate that differences between age groups in the rates of intra-individual change are significant for omission ($p < .01$, effect size = .02), distortion ($p < .0001$, effect size = .08), and perseveration ($p < .01$, effect size = .02) errors. Note that while intra-individual change in rotation errors was highly significant, there was no significant effect of Age Group because even the youngest age group showed intra-individual increases in rotational errors. The interaction between Gender and Error Type reflects different profiles of intra-individual change for men and women. In particular, the rate of increase in omission errors was greater for men than women, $p < .001$ (effect size = .03; mean yearly rates of change were .01 ± .06 for men and –.01 ± .09 for women). MANCOVA with WAIS Vocabulary score as a covariate again yielded a similar pattern of results. The only substantive change was that the age-associated intra-individual increase in rotation errors did not reach significance after controlling for Vocabulary.

Correlations between longitudinal change in visual acuity and changes in BVRT errors were near zero, indicating no relationship for any error type.

DISCUSSION

Previous investigations have consistently shown increases in BVRT total error scores with normal aging (Arenberg, 1978; Benton et al., 1981; Mormont, 1984; Robertson-Tchabo & Arenberg, 1989; Shichita et al., 1986). Our investigation extends these findings by demonstrating significant age differences for all types of BVRT errors in community-dwelling men and women ranging from 20 to

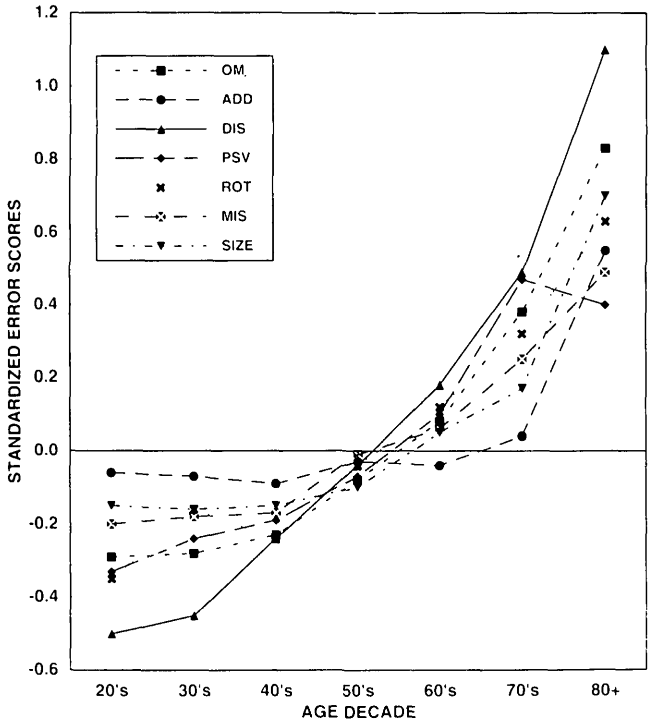

Figure 1. Mean z-transformed errors for the 7 age groups by specific error type. Z-scores are computed across age separately for each error type. Abbreviations are: OM omissions; ADD additions; DIS distortions; PSV perseverations; ROT rotations; MIS misplacements; SIZE size errors.

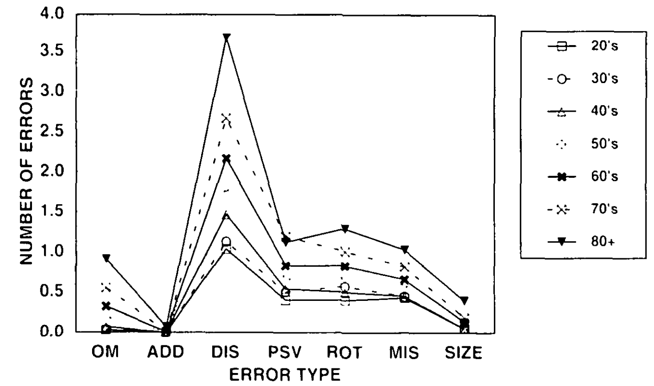

Figure 2. Error profiles for the 7 age groups. Abbreviations as in Figure 1.

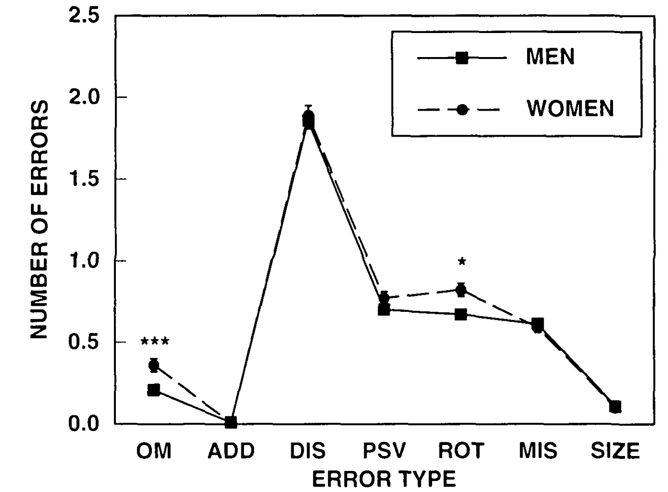

Figure 3. Error profiles for men (solid line) and women (dashed line) across all ages. Women make significantly more omission and rotation errors, but there are no differences with respect to other error types. ***$p < .001$; *$p < .05$. Abbreviations as in Figure 1.

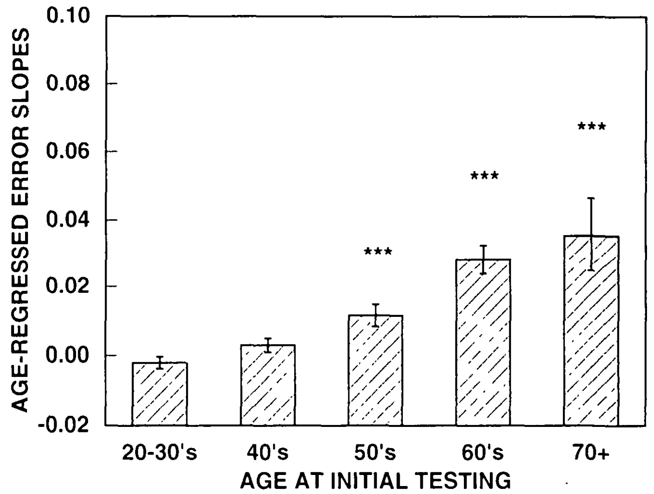

Figure 4. Age-regressed error slopes as a function of age at initial testing. Slope estimates are based on 3 BVRT assessments and reflect the rates of intra-individual change in errors. Note that intra-individual increases in errors with age do not reach significance until after age 50. ***$p < .001$.

102 years of age. Cross-sectional analyses indicated that all types of errors increased significantly across age groups. The overall increase in errors with age was similar for men and women.

Against this background of global age differences in errors, there were significant differences in error profiles between age groups, reflecting different magnitudes of age-associated increases for the specific error types. While the general shape of the error profile was maintained across age groups, age differences were greatest for distortion, omission, and rotation errors. There were also significant differences in error profiles for men and women. While there was no sex difference in overall BVRT performance, females made more omission and rotation errors than males. These gender differences account for less than 1% of the variance. Nevertheless, the gender difference in rotational errors is intriguing because it is consistent with a large body of evidence indicating that the male advantage on tests of spatial rotational ability is a large and replicable cognitive sex difference (Linn & Petersen, 1985; Masters & Sanders, 1993).

Consistent with the cross-sectional results, longitudinal analysis of intra-individual age change indicated significant increases in overall BVRT errors with age for both men and women. Analysis of the slope "scores" revealed that intra-individual increases in errors with age were significant only

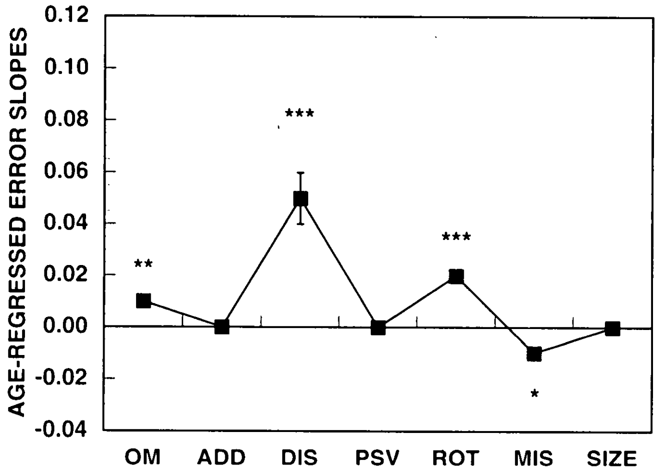

Figure 5. Profile of average slope "scores" for the 7 different error types. For all age groups combined, intra-individual increases in errors are significant only for omission, distortion, and rotation errors, and misplacement errors appear to decrease with age. ***$p < .001$; **$p < .01$; *$p < .05$. Abbreviations as in Figure 1.

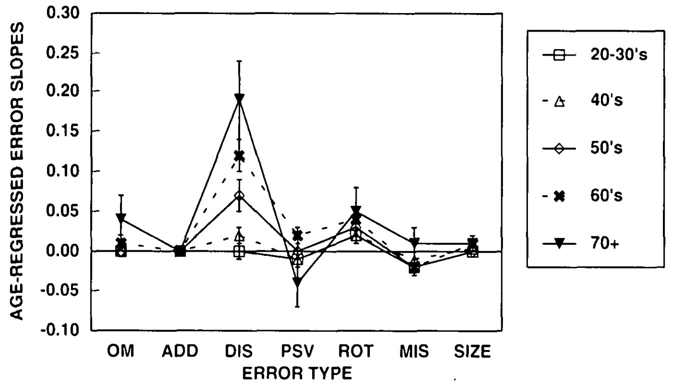

Figure 6. Profiles of average slope "scores" for each of the 5 age groups, defined by age at initial testing. Abbreviations as in Figure 1.

for subjects age 50 and older at the time of initial testing, with greatest rates of change for the 70 and older age group, as has been previously reported by Arenberg (1978, 1987). In contrast to cross-sectional age differences observed for all error types, significant intra-individual increases in errors over the three measurements were observed only for distortion, omission, and rotation errors. It is important to note that in the latter analyses the slope "scores" provide indices of the *yearly rates* of age changes for the specific error types and yield information complementary to the cross-sectional analyses. The three types of errors which show the steepest increases with age are the same as those showing the largest cross-sectional age differences and are thus most susceptible to effects of normal aging. Age-associated increases in BVRT errors are not due to declines in vision, as longitudinal changes in visual acuity were unrelated to BVRT performance in our sample.

Longitudinal analyses also confirmed the differences in error profiles between age groups, defined by age at first testing. Comparisons of error profiles across age groups revealed significant differences among age groups for rates of change in distortion, omission, and perseveration errors. Distortion and omission errors increased more rapidly for the oldest age groups, while perseveration errors decreased over repeated assessments in the oldest group. It is notable that there were no significant differences in rotation errors between age groups, because even the youngest groups showed increasing rotational errors over time, and rates of change were comparable among groups. This finding is consistent with evidence that performance on spatial rotational tasks peaks in late adolescence/early adulthood and declines thereafter (Vandenberg & Kuse, 1978).

The differential increases in particular error types are notable, as specific errors have been associated with a variety of neurological disorders, including AD. While distortion errors are not *selectively* increased in AD patients, differential increases in omission (Eslinger et al., 1988; LaRue et al., 1986; Vollant et al., 1986) and perseveration (Eslinger et al., 1988; Vollant et al., 1986) errors have been reported in AD. Our observations of relatively greater increases in omission errors in normal aging suggest some continuity between pathological and normal cognitive aging. This continuity accords with neuropathological data indicating similarity in the topographic distribution of brain regions most vulnerable to pathological change in nondemented elderly subjects (Arriagada, Marzloff, & Hyman, 1992) and in patients with AD (Arnold, Hyman, Flory, Damasio, & Van Hoesen, 1991). Alternatively, it is possible that subjects with increased omission errors are in a preclinical stage of AD, which will be manifested with continued longitudinal assessments. Additionally, the differential effects of age for the various error types suggest that changes in different brain regions may underlie specific BVRT errors.

In contrast, the absence of increased perseveration errors in the oldest age group may reflect a discontinuity between normal and pathological cognitive aging. The relative decline in perseveration errors was observed in both cross-sectional and longitudinal analyses. It was somewhat surprising, because perseveration errors on the BVRT are more common with frontal lesions (Vilkki, 1989), and frontal structures are vulnerable to brain changes in normal aging (Coffey et al., 1992; Pfefferbaum et al., 1990) and AD (Chawluk et al., 1990; Pfefferbaum et al., 1990). The relative stability of perseveration errors in the oldest groups suggests that perseverations and the rate of increase in perseveration errors may be more predictive of pathological cognitive change. However, it is also possible that there was selection against frontal lobe pathology or selection for particularly intact frontal lobes in the essentially self-selection screening process for the oldest groups at entry and retention in the longitudinal study. Participants entering and remaining in the study after age 70 were likely to have exceptionally good health and strong motivation and may also have been above average in frontal lobe functions — for example, organizational and planning skills, verbal fluency. Alternatively, it is possible that errors in older individuals are more likely to be scored as distortions, because their declining memory results in a distorted design rather than an exact duplication of a preceding design.

In addition to the differences in error profiles among age groups, the longitudinal analyses also indicated significant differences in error profiles between men and women. Men showed steeper rates of increases in omission errors with age. Thus, while females showed greater numbers of omission errors, the rate of intra-individual change in these errors was greater in men, indicating steeper declines in memory. A greater rate of decline in aging men accords with recent neuroimaging studies indicating steeper age-associated increases in brain atrophy in men compared with women (Gur et al., 1991; Kaye, DeCarli, Luxenberg, & Rapoport, 1992).

The differences in error profiles across age and gender groups cannot be explained by group differences in sampling schemes or general intelligence. When analyses were repeated covarying WAIS Vocabulary score, there was no difference in the pattern of results. Similarly, Arenberg (1978) has reported that WAIS Vocabulary scores are not significantly correlated with BVRT performance. We chose Vocabulary rather than education as an indicator of individual differences in general intelligence, because cultural factors leading to educational attainment in males and females in this country have changed dramatically over time. While Shichita et al. (1986) reported that education was a significant predictor of age-associated change in BVRT performance, their sample comprised individuals age 69–71 and was thus homogeneous with respect to age cohort. As our sample spanned a broad range of ages, educational attainment was influenced by cultural factors which differed between men and women and across age groups and would not be a valid indicator of individual differences in ability.

In summary, our results indicate age-related changes for specific error types, greatest for distortion, omission, and rotation errors. Age differences in error profiles were observed in both men and women. For all age groups combined, however, females made more rotation and omission errors than men. The differences in error profiles across age groups and between men and women suggest the possibility that different mechanisms and brain regions may underlie age differences and rates of change with age for specific types of errors. Neuroimaging assessments have been initiated recently in the BLSA sample and will permit examination of specific BVRT changes in relation to longitudinal change in regional brain structure and function.

ACKNOWLEDGMENTS

We thank Melissa Kitner-Triolo, Liz Burke, Judy Friz, and Armando San Juan for their assistance in data collection and entry, Dr. David Arenberg for his many contributions to these studies, Dr. Paul Costa for his support and comments, and the BLSA participants for their cooperation.

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Received March 11, 1994
Accepted November 28, 1994