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Changes in Intellectual Functioning Associated with Normal Aging

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Abstract

Declines in IQ scores with advancing age have been observed in each successive revision of the Wechsler Intelligence Scales. This study examined age-related changes on the fourth edition of the Wechsler Adult Intelligence Scale and compared these to the effects seen on the 1955, 1981, and 1997 standardizations of the scales. The most pronounced declines were in measures of processing speed and nonverbal reasoning. Declines in nonverbal reasoning were similar on timed and un-timed measures. Verbal abilities remained relatively stable across the life span. General intelligence as assessed by the Full Scale IQ was reduced about 1 *SD* by age 75 when corrections for age were removed. Age-related declines have become less pronounced since 1955, particularly on measures of processing speed. This effect was essentially linear, unrelated to concurrent IQ increases in the general population, and paralleled a 9-year increase in life expectancy during this time period.

Keywords: Aging; WAIS IV; Intelligence

Introduction

Declines in IQ scores with advancing age have been observed in each successive revision of the Wechsler Adult Intelligence Scales (WAIS). Wechsler (1939, 1958) concluded that intelligence declines with age. Corrections for these age-related declines have therefore been incorporated into the calculation of IQs since the publication of the Wechsler-Bellevue Intelligence Scale (Wechsler, 1939) to assist clinicians in distinguishing between normal age-related cognitive decline and impairment due to neurological or psychiatric disorders. Failure to account for age-related changes can lead to the misdiagnosis of cognitive impairment or dementia in the normal elderly (Nadler, Mittenberg, DePiano, & Schneider, 1994). Routine subtest and Index score corrections for the patient's age were included beginning with the 1997 WAIS-third edition (WAIS-3) and subsequently in the 2008 WAIS-fourth edition (WAIS-4).

Kaufman (1990) showed that age-related declines were more pronounced on the subtests that measure nonverbal intelligence than verbal intelligence by removing corrections for age from the standardization sample data for the WAIS-revised (WAIS-R; 1981). These differential score reductions were not explained by differences between age groups in educational levels. Speed of thought process (as measured by the Digit Symbol-Coding subtest) showed the greatest decline with age. Reductions in performance on the Block Design subtest were more pronounced than score changes on the Vocabulary and Digit Span subtests, which were relatively stable between the ages of 20 and 74.

Although these declines were inferred from a cross-sectional comparison of age groups in the WAIS-R standardization sample, longitudinal comparisons have demonstrated similar age-related changes. Kaufman (1990) compared age cohorts across the 25-year span between the standardization of the WAIS (Wechsler, 1955) and WAIS-R to this end. Longitudinal comparisons showed pronounced decline in nonverbal intelligence and relative preservation of verbal intelligence between

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the ages of 20 and 74. The reductions were not attributable to educational differences between age groups because each age cohort on the WAIS-R was compared with the performance of the same cohort 25 years earlier. The patterns of decline were also independent of population increases in IQ (Flynn, 1984) that occurred during the time interval between the two standardizations.

In a replication of this methodology using standardization data from the WAIS-3 and WAIS-R, Kaufman (2001) found similar declines in nonverbal intelligence and relative preservation of verbal intelligence using both cross-sectional and longitudinal comparisons between younger and older age groups. Ryan, Sattler, and Lopez (2000) examined differences in the WAIS-3 subtest scores between age groups in the standardization sample. The greatest age-related declines were observed on subtests that measure speed of thought process (e.g., Digit Symbol-Coding), with relative preservation of performance on subtests that assess attention and concentration (i.e., working memory) such as Digit Span. Verbal subtests (such as knowledge of word meanings as assessed by the Vocabulary subtest) showed relatively stable performance across the life span, whereas measures of nonverbal intelligence (such as Block Design) declined more precipitously. In Sweden, cross-sectional and longitudinal comparisons of the effect of age on Block Design subtest performance also showed similar declines after 55 years of age that were unrelated to educational attainment (Ronnlund & Nilsson, 2006). Subtests that show the greatest sensitivity to aging also showed the greatest age-related variability in scores (Ardila, 2007).

It was hypothesized that patterns of age-related decline on the WAIS-4 would be similar to those observed on prior versions of the Wechsler Intelligence Scales. The most pronounced declines were expected on measures of processing speed and nonverbal intelligence, with relative preservation of verbal abilities. The WAIS-4 "Manual" (Wechsler, 2008a) does not directly provide information about the extent of age-related changes in subtests, Indexes, or Full Scale IQs because these scores are inherently corrected for the effects of age. However, it is possible to remove these age corrections by using normative data for the 20–34-year-old reference group (rather than the age specific tables) to derive subtest scores and to use the resulting subtest scores that are therefore not age corrected to derive age neutral Index and IQ scores. This procedure allows a cross-sectional view of age-related changes in intellectual functions. Similar procedures can be followed to derive subtest and IQ scores that are not age corrected from the 1955 WAIS, 1989 WAIS-R, and 1997 WAIS-3 to allow a longitudinal view of age-related changes in intellectual function.

Materials and Methods

The WAIS-4 (Wechsler, 2008b) was standardized on a sample of 2,200 adults between the ages of 16 and 90 that were selected by stratified sampling to represent the demographic characteristics of the U.S. population. The sample was stratified to match the 2005 Census by age, gender, educational levels, geographic region of residence, and ethnicity. Individuals were excluded if they had neurological or psychiatric disorders that might depress test performance, were taking medication that might affect test performance, had a history of an episode of unconsciousness longer than 20 min and of radiation or electroconvulsive therapy, or had uncorrected impairment of vision or hearing. Scaled score equivalents of raw score totals for each WAIS-4 subtest are presented in the "Manual" for 13 age groups and a reference group of individuals between 20 and 34 years of age. Group demographic characteristics and sample sizes are also reported in the "Manual" (Wechsler, 2008b).

Table 1. Mean scaled scores for the core WAIS-4 subtests without corrections for age

Age	V	I	S	DS	A	BD	MR	VP	CD	SS
16–17	9	10	9	10	10	10	10	11	10	10
18–19	9	10	10	10	10	10	10	11	10	10
20–24	9	10	10	10	10	10	10	11	10	10
25–29	10	10	10	10	10	10	10	10	10	10
30–34	10	10	10	10	10	10	10	10	10	10
35–44	11	11	10	10	11	9	10	10	9	10
45–54	11	11	10	10	11	9	9	9	9	9
55–64	11	11	10	9	10	8	8	8	8	8
65–69	11	11	10	9	10	7	7	8	7	7
70–74	10	11	10	8	9	7	6	7	6	7
75–79	10	11	9	8	9	6	6	7	5	6
80–84	10	10	9	7	9	6	5	6	5	5
85–90	9	9	8	7	8	5	4	6	4	4

Notes: WAIS-4 = Wechsler Adult Intelligence Scales, 4th edition; V = Vocabulary; I = Information; S = Similarities; DS = Digit Span; A = Arithmetic; BD = Block Design; MR = Matrix Reasoning; VP = Visual Puzzles; CD = Coding; SS = Symbol Search.

Table 2. Mean WAIS-4 process subtest scaled scores without corrections for age

Age	Block Design		Digit Span		
	Standard	No time bonus	Forward	Backward	Sequencing
16–17	10	10	10	10	10
18–19	10	10	10	10	10
20–24	10	10	10	10	10
25–29	10	10	10	10	10
30–34	10	10	10	10	10
35–44	9	10	10	10	10
45–54	9	9	9	10	10
55–64	8	8	9	9	9
65–69	7	8	9	9	9
70–74	7	7	9	9	8
75–79	6	7	9	9	8
80–84	6	6	9	8	6
85–90	5	5	8	8	6

Note: WAIS-4 = Wechsler Adult Intelligence Scales, 4th edition.

Table 3. Mean WAIS-4 Index scores and FSIQ's without corrections for age

Age	VC	PR	WM	PS	FSIQ
16–17	96	102	100	100	99
18–19	98	102	100	100	100
20–24	100	102	100	100	100
25–29	100	100	100	100	100
30–34	100	100	100	100	100
35–44	103	98	102	97	100
45–54	103	94	102	94	98
55–64	103	88	97	89	94
65–69	103	84	97	84	91
70–74	102	81	92	81	86
75–79	100	79	92	76	84
80–84	98	75	89	74	80
85–90	96	71	86	68	75

Notes: WAIS-4 = Wechsler Adult Intelligence Scales, 4th edition; VC = Verbal Comprehension Index; PR = Perceptual Reasoning Index; WM = Working Memory Index; PS = Processing Speed Index; FSIQ = Full Scale IQ.

For the current study, the mean raw score that corresponded to average performance for each subtest was determined for each age group. Raw scores were converted to subtest scaled scores that were uncorrected for age (Tables 1 and 2) using the scaled score equivalents for the 20–34-year-old reference group. These uncorrected subtest scaled scores were summed to produce Index and Full Scale IQ scores that were not corrected for age (Table 3). The mean raw score that corresponded to performance 1 *SD* above and below average was determined for each age group. Raw score standard deviations were converted to scaled score standard deviations that were uncorrected for age (Table 4) using the scaled score equivalents for the 20–34-year-old reference group. These uncorrected standard deviations were summed to produce standard deviations for the Indexes and Full Scale IQs that were not corrected for age (Table 5) using the method for determining the variance of a linear combination described by Nunnally (1978).

Average subtest scaled scores, Full Scale IQs, and standard deviations that were not corrected for age were derived for the 70–74-year-old groups in the WAIS-3 (Wechsler, 1997), WAIS-R (Wechsler, 1981), and WAIS (Wechsler, 1955) standardization samples (n = 200, 160, and 80, respectively) using procedures that were similar to those described earlier for the WAIS-4 (Table 6).

Average WAIS-4 subtest, Index, and IQ scores were correlated with the mean ages of the 13 age groups to determine if significant linear age-related declines in performance occurred (Table 7). When declines were present, independent *t*-tests were used to compare the performance of the 20–34-year-old reference group to that of the older age group that performed 1 or more standard deviations lower to determine if these declines were statistically significant. WAIS-4 Index and IQ score variances for each age group were correlated with the mean ages of the groups to determine if significant linear relationships were present between performance variability and age. Age neutral subtest and IQ scores for the 70–74-year-old groups

Table 4. Standard deviations for the core WAIS-4 subtests without corrections for age

Age	V	I	S	DS	A	BD	MR	VP	CD	SS
16–17	2.5	3.0	2.5	2.5	2.5	3.0	3.5	3.0	3.0	3.0
18–19	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0	3.0	3.0
20–24	2.5	3.0	3.0	3.0	3.0	3.0	3.5	3.0	3.0	3.0
25–29	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30–34	3.5	3.0	3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35–44	3.0	3.0	3.5	3.0	3.0	2.5	3.0	2.5	2.5	3.0
45–54	3.0	3.0	3.5	2.5	2.5	3.0	3.0	2.0	3.0	3.0
55–64	3.0	3.5	3.5	3.0	2.5	2.5	2.5	2.0	2.5	2.5
65–69	3.5	3.5	3.5	3.0	2.5	2.5	3.0	2.0	2.5	2.5
70–74	3.5	3.5	3.0	3.0	2.5	2.0	3.0	2.0	2.5	2.5
75–79	3.5	3.5	3.0	3.0	2.0	2.5	2.5	1.5	2.5	2.5
80–84	3.0	4.0	3.0	3.0	2.5	2.0	2.0	2.0	2.5	2.0
85–90	3.5	3.5	2.5	3.0	2.5	1.5	2.5	2.0	2.5	2.0

Notes: WAIS-4 = Wechsler Adult Intelligence Scales, 4th edition; V = Vocabulary; I = Information; S = Similarities; DS = Digit Span; A = Arithmetic; BD = Block Design; MR = Matrix Reasoning; VP = Visual Puzzles; CD = Coding; SS = Symbol Search.

Table 5. Standard deviations of the WAIS-4 Index scores and FSIQ's without corrections for age

Age	VC	PR	WM	PS	FSIQ
16–17	12.5	15.5	14.0	14.0	13.0
18–19	14.5	15.5	14.0	14.0	15.0
20–24	14.5	15.5	14.0	14.0	15.0
25–29	14.5	15.5	14.0	14.0	15.0
30–34	16.5	15.5	14.0	14.0	16.0
35–44	16.5	13.5	14.0	13.5	14.5
45–54	16.5	14.0	14.0	13.5	14.0
55–64	16.5	11.5	14.0	13.0	14.0
65–69	16.5	12.0	14.0	13.0	15.0
70–74	16.5	11.5	14.0	10.5	13.0
75–79	16.5	9.5	14.0	13.5	13.0
80–84	16.5	9.5	14.0	11.0	12.5
85–90	16.0	10.5	14.5	11.5	13.0

Notes: WAIS-4 = Wechsler Adult Intelligence Scales, 4th edition; VC = Verbal Comprehension Index; PR = Perceptual Reasoning Index; WM = Working Memory Index; PS = Processing Speed Index; FSIQ = Full Scale IQ.

Table 6. Average scores for 70–74-year-old persons on successive Wechsler IQ tests without age corrections

Test	Vocabulary (mean [*SD*])	Block Design (mean [*SD*])	Digit Span (mean [*SD*])	Coding (mean [*SD*])	Full Scale IQ (mean [*SD*])
1955 WAIS	9 (3.0)	7 (2.5)	8 (2.5)	4 (3.0)	80 (12.5)
1981 WAIS-R	9 (3.0)	6 (2.0)	8 (2.5)	5 (3.0)	82 (10.5)
1997 WAIS-3	10 (3.5)	7 (2.0)	8 (2.5)	6 (2.0)	85 (13.0)
2008 WAIS-4	10 (3.5)	7 (2.0)	8 (3.0)	6 (2.5)	86 (13.0)

in the WAIS, WAIS-R, WAIS-3, and WAIS-4 standardization samples were compared using one-way analyses of variance to determine if significant changes in the pattern of age-related decline have occurred over time.

Results

Table 1 shows average changes associated with age on the WAIS-4 subtests. The most precipitous age-related decline occurred on the Coding subtest, which measures the speed of thought process. Mean Coding subtest scores were negatively correlated with age as a result of this decline (Table 7). Average reductions reached 1 *SD* at age 65, $t(798) = 12.74$, $p < .001$, and 2 *SD* by age 85, $t(698) = 12.93$, $p < .001$, compared with 20–34-year olds. Subtests that assess nonverbal reasoning were more sensitive to age than those that measure verbal intelligence. Each of the nonverbal subtests (Block Design,

Table 7. Correlations between average WAIS-4 IQ, Index, and subtest scores and mean age

	r-value	p-value
FSIQ	−.92	<.001
Verbal Comprehension Index	.10	.76
Perceptual Reasoning Index	−.98	<.001
Working Memory Index	−.85	<.001
Processing Speed Index	−.96	<.001
Vocabulary	.29	.35
Information	.14	.65
Similarities	−.50	.08
Digit Span	−.91	<.001
Arithmetic	−.65	.02
Block Design	−.97	<.001
Matrix Reasoning	−.95	<.001
Visual Puzzles	−.99	<.001
Coding	−.96	<.001
Symbol Search	−.95	<.001

Notes: All probabilities are two-tailed with $df = 11$. WAIS-4 = Wechsler Adult Intelligence Scales, 4th edition.

Matrix Reasoning, and Visual Puzzles) showed steeper linear gradients of decrement with age than the any of the verbal measures. Declines of 1 *SD* occurred by age 65 on the Block Design, $t(798) = 12.74$, $p < .001$, and Matrix Reasoning subtests, $t(798) = 11.72$, $p < .001$. Comparison of Block Design scores using the standard bonus points for more rapid solutions and scores without these bonus points for speed (Table 2) demonstrated a decline of 1 *SD* by age 70 and 2 *SD* at age 80 with both scoring methods when compared with the performance of the 20−34-year-old reference group.

In contrast, the Vocabulary and Information subtests characterized improvements in verbal ability through middle age, and performance in the average range was maintained throughout the life span in comparison to ability at 20−34 years of age. Average subtest scores on Vocabulary and Information were not significantly correlated with age as a result. Subtests that assess attention and concentration declined more gradually, reaching 1 *SD* at age 80 on the Digit Span subtest, $t(698) = 9.26$, $p < .001$. Digit Span performance was negatively correlated with age.

Patterns of change with age in the WAIS-4 Index scores (Table 3) reflect these changes in underlying subtest performance. Compared with 20−34-year olds, Index score declines of >1 *SD* occurred in Processing Speed, $t(798) = 14.24$, $p < .001$, and Perceptual Reasoning, $t(798) = 13.88$, $p < .001$, by age 65. Average Processing Speed and Perceptual Reasoning Index scores were negatively correlated with age as a result (Table 7). Similar reduction in Working Memory was not present until 85 years of age, $t(698) = 9.21$, $p < .001$. Average Working Memory Index scores were negatively correlated with age. More pronounced loss in the component ability to perform digit sequencing was seen than on the Digit Span subtest forward or backward sections (Table 2). Relatively invariant scores on the Verbal Comprehension Index confirmed that verbal intelligence was

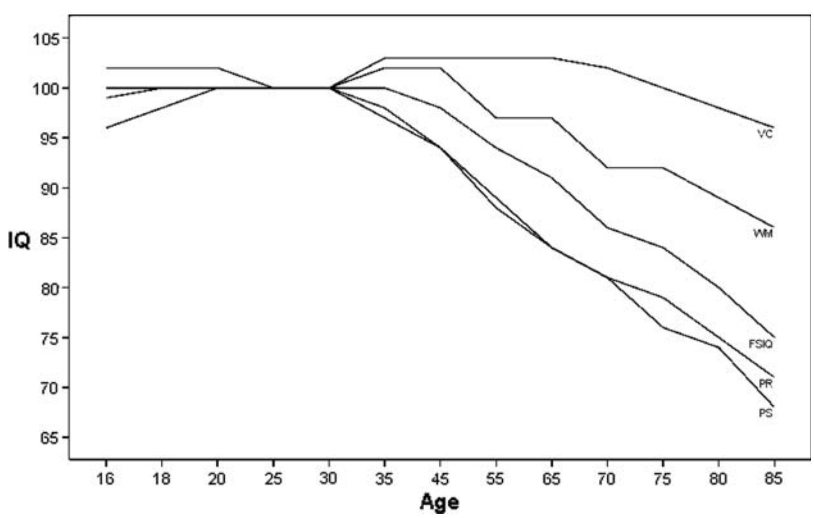

Fig. 1. Changes in mean WAIS-4 Index scores and Full Scale IQs with increasing age. VC = Verbal Comprehension Index; WM = Working Memory Index; FSIQ = Full Scale IQ; PR = Perceptual Reasoning Index; PS = Processing Speed Index.

resistant to changes across the life span. Overall intellectual ability as assessed by the Full Scale IQ was about 1 *SD* lower than the 20–34-year-old reference group by 75 years of age, $t(698) = 9.86$, $p < .001$. There was a significant linear decline with age in average IQ scores (Table 7). Fig. 1 depicts these Index and IQ score changes graphically.

Variability in the Full Scale IQ (Table 5) also declined with age, $r(11) = -.81$, $p = .03$. Variance in the underlying Processing Speed, $r(11) = -.81$, $p = .001$, and Perceptual Reasoning Indexes, $r(11) = -.95$, $p < .001$, similarly decreased. In contrast, variability in the Verbal Comprehension Index increased significantly with age, $r(11) = .72$, $p = .006$. There was no significant relationship between age and variance in the Working Memory Index, $r(11) = .44$, $p = .14$.

Comparisons between the effects of age across four population samples that span the 53-year period between standardization of the WAIS and the WAIS-4 appear in Table 6. The performance of the 70–74-year-old groups relative to each of the four concurrent 20–34-year-old reference samples is shown. The 70–74-year-old groups were selected for comparison because this is the oldest age range common to the four standardizations and is also the age range that corresponds to the average life span during this time period. The Vocabulary, Block Design, Digit Span, and Digit Symbol (or Coding) subtests were selected because they are common to the various WAIS revisions and are the subtests that correlate most highly with their respective WAIS-4 Indexes (Index scores were not available for the WAIS or WAIS-R). Nonverbal reasoning (Block Design) and attention span (Digit Span) showed declines by age 70–74 that have remained essentially constant from 1955 to 2008 compared with respective reference groups. The Vocabulary knowledge of persons in their 70s is somewhat better preserved in more contemporary population samples, $F(3, 536) = 4.11$, $p = .007$. Average Vocabulary scores were .31 *SD* higher in 2008 than they were in 1955. Coding subtest scores suggest that speed of thought process in 70–74-year olds has improved in an essentially linear fashion during the past 53 years, $F(3, 536) = 14.59$, $p < .001$. The effect size of this improvement was .72 *SD* in magnitude. Relative to contemporaneous 20–34-year olds, the Full Scale IQ of the average person aged 70–74 has also increased in a systematic manner from 1955 to 2008, $F(3, 536) = 5.37$, $p = .001$. Mean IQs have improved by .47 *SD* during the past 53 years.

Discussion

Patterns of age-related change on the WAIS-4 are similar to those that have been observed in both cross-sectional and longitudinal analyses of prior versions of the scale (Kaufman, 1990, 2001; Ryan, Sattler, & Lopez, 2000). Declines in Full Scale IQ with advancing age are predominantly due to slowing of thought process and reduced nonverbal reasoning ability. Verbal intelligence and working memory are relatively resistant to advancing age.

This pattern of intellectual decline is similar to that seen in diffuse degenerative process such as Alzheimer's disease or dementia due to head trauma (Wechsler, 2002, 2008b). Relative preservation of verbal abilities and deterioration of nonverbal intelligence is consistent with Ribot's (1882) law. This principle states that cognitive abilities learned earliest or rehearsed more are most resistant to conditions that affect the brain.

Imaging studies support the inference that age-related cognitive decline is associated with atrophic changes in the brain. Cross-sectional and longitudinal structural MRI studies indicate that normal aging is associated with a 50% reduction in brain volume (Decarli et al., 2005; Good et al., 2001; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003). Cell loss is minimal prior to age 50 and accelerates substantially thereafter (Decarli et al., 2005). Systematic age-related atrophic changes in white matter have also been linked to the cognitive declines that characterize normal aging (Brickman, Habeck, Zarahn, Flynn, & Stern, 2007). In addition to the decline observed on intelligence tests, changes in memory and executive function are also likely to be associated with these atrophic changes (Mittenberg, Seidenberg, O'Leary, & DiGiulio, 1989).

Comparison of the effects of age across the four population samples from the WAIS to the WAIS-4 suggests that the intelligence and speed of thought process of average persons aged 70–74 have increased in an essentially linear manner relative to 20–34-year olds from 1955 to 2008. It is possible that these increases are related to improvements in medicine and general health. The average life span in the USA was 69.1 in 1955, 73.9 in 1981, 76.5 in 1997, and 78.1 in 2007 (National Center for Health Statistics, 2006, 2007). These average life spans correlate .73 with the average IQ increases in 70–74-year-old groups from 1955 to 2008. It is also possible that the observed increase in scores is in part due to progressively more rigorous exclusion from the standardization samples over time of persons with medical conditions that might reduce cognitive performance. Such conditions are likely to differentially affect older more than younger persons.

IQ scores in the general population have also increased over time (Flynn, 1984). Manuals for Wechsler's Intelligence Scales show that Full Scale IQ increased 7.5 points between standardizations of the WAIS and the WAIS-R, 2.9 points from the WAIS-R to the WAIS-3, and 2.9 points between the standardization of the WAIS-3 and the WAIS-4. However, these increases are unlikely to account for the progressive improvement shown by 70–74-year olds across standardization samples. These latter improvements occurred relative to younger reference samples that were tested concurrently using the same Wechsler revision, and thus are independent of population increases that occurred over time relative to historical normative data. The

WAIS-4 would actually have produced lower IQs than its predecessors if the tests were administered simultaneously. However, Wechsler IQs correlate between .88 and .94 across revisions and can therefore be compared, although successive versions of scales do not contain identical subtests (Wechsler, 1981, 2002, 2008b). Changes in the test are therefore less likely to explain the observed improvements.

Older and younger age groups typically differ in educational levels, and these differences may partially explain the lower scores of less educated older samples in cross-sectional normative data. For example, in the WAIS-4 standardization, 25% of the 20–34-year-old reference group had college or higher degrees compared with 20% of the 70–74-year-old group. Education accounts for approximately 32% of the variance in performance on the Verbal Comprehension Index, but only about 18% of the variance in performance on the Processing Speed and Perceptual Reasoning Indexes (Heaton, Taylor, & Manly, 2003). Differences between older and younger age groups in educational levels are therefore less likely to explain age-related decline on nonverbal measures, particularly given the lack of significant decline observed on verbal measures. Statistical control for differences between age groups in educational levels might better clarify the extent to which the observed differences in intellectual decline were due to age *per se* or differences between age cohorts in educational levels.

Longitudinal retesting of an age cohort over time might also clarify the extent of intellectual decline due to aging rather than differences between cohorts in educational levels. However, longitudinal studies may suffer from selective attrition of less educated persons. For example, 20% of 20–24-year olds had education beyond high school in 1955 compared with almost 40% of this birth cohort in the WAIS-4 standardization 53 years later (Wechsler, 1955, 2008b). Longitudinal comparisons may therefore underestimate age-related declines. Given these limitations, prior research (Kaufman, 1990, 2001; Ronnlund & Nilsson, 2006) suggests that both cross-sectional and longitudinal methodologies appear to converge on the conclusion that characteristic patterns of change occur with age on the Wechsler Intelligence Scales.

Current cross-sectional analyses suggest that population variability in intellectual functions also declines as a result of the aging process. This restriction in range occurred on the Indexes that showed mean performance declines (Processing Speed and Perceptual Reasoning). No reduction in variability was found on the Verbal Comprehension Index, which did not decline significantly due to aging. These results suggest that as ability declines, the range of those abilities in the population also declines. This effect may be visible at the population level. For example, there are more Nobel prizes or Olympic gold medals awarded for the achievements of 20–34-year olds than 70–74-year olds. An equal number of awards are given to average persons in either age group.

Ardila (2007) reported that score dispersions increased as the mean scores decreased on the WAIS-3, a finding that initially appears to be contrary to the current results. Ardila's conclusions were based on a ratio of subtest raw score standard deviations to subtest raw score means. Current results were based on scaled score standard deviations (which declined with age as the means declined). Whether the ratio percentage of the mean used by Ardila (2007) or the Index score standard deviations reported here better characterize the actual variance in intelligence depends on whether one views variability in relative or absolute terms.

The age neutral standard deviations and mean scores reported here should be considered estimates rather than precise population parameters, in part because these were derived from summary rather than raw standardization data. For example, if a raw score of 15 corresponded to a scaled score of 10 for a given age group, the actual mean raw score could have ranged from 14.5 to 15.5. When the subtest scores were combined to produce Index and IQ scores, these rounding errors may have compounded. Alternatively, given the large sample sizes and normally distributed scores in the standardization sample, these rounding errors may be normally distributed and therefore have averaged to zero. However, analyses using the raw standardization data might provide more exact estimates of the effects of age on the WAIS-4 in the population. Given the effects of age observed in the current and prior studies, clinicians should incorporate corrections for age in their interpretation of cognitive tests.

Conflict of Interest

None declared.

References

Ardila, A. (2007). Normal aging increases cognitive heterogeneity: Analysis of dispersion in WAIS-III scores across age. *Archives of Clinical Neuropsychology*, *22*, 1003–1011.

Brickman, A. M., Habeck, C., Zarahn, E., Flynn, J., & Stern, Y. (2007). Structural MRI covariance patterns associated with normal aging and neuropsychological functioning. *Neurobiology of Aging*, *28*, 284–295.

DeCarli, C., Massaro, J., Harvey, D., Hald, J., Tullberg, M., Auf, R., et al. (2005). Measures of brain morphology and infarction in the Framingham Heart Study: Establishing what is normal. *Neurobiology of Aging*, *26*, 491–510.

Flynn, J. R. (1984). The mean IQ of Americans: Massive gains 1932 to 1978. *Psychological Bulletin*, *95*, 29–51.

Good, C. D., Johnsrude, I. S., Ashburner, J., Henson, R. N., Friston, K. J., & Frackowiak, R. S. (2001). A voxel-based morphometric study of ageing in 465 normal adult human brains. *NeuroImage*, *14*, 21–36.

Heaton, R. K., Taylor, M. J., & Manly, J. (2003). Demographic effects and use of demographically corrected norms with the WAIS-III and WMS-III. In D. S. Tulsky (Ed.), *Clinical interpretation of the WAIS-III & WMS-III.* San Diego, CA: Academic Press.

Kaufman, A. S. (1990). *Assessing adolescent and adult intelligence.* Needham, MA: Allyn and Bacon.

Kaufman, A. S. (2001). WAIS-III IQs, Horn's theory, and generational changes from young adulthood to old age. *Intelligence*, *29*, 131–167.

Mittenberg, W., Seidenberg, M., O'Leary, D., & DiGiulio, D. (1989). Changes in cerebral functioning associated with normal aging. *Journal of Clinical and Experimental Neuropsychology*, *11*, 918–932.

Nadler, J. D., Mittenberg, W., DePiano, F. A., & Schneider, B. A. (1994). Effects of patient age on neuropsychological test interpretation. *Professional Psychology: Research and Practice*, *25*, 288–295.

National Center for Health Statistics. (2006). *Deaths, preliminary data for 2006.* Hyattsville, MD: Author.

National Center for Health Statistics. (2007). *Heath, United States*. Hyattsville, MD: Author.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York: McGraw Hill Inc.

Resnick, S. M., Pham, D. L., Kraut, M. A., Zonderman, A. B., & Davatzikos, C. (2003). Longitudinal magnetic resonance imaging studies of older adults: A shrinking brain. *Journal of Neuroscience*, *23*, 3295–3301.

Ribot, T. (1882). *Diseases of memory.* New York: Appleton-Century-Crofts.

Ronnlund, M., & Nilsson, L. G. (2006). Adult life-span patterns in WAIS-R Block Design performance: Cross-sectional versus longitudinal age gradients and relations to demographic factors. *Intelligence*, *34*, 63–78.

Ryan, J. J., Sattler, J. M., & Lopez, S. J. (2000). Age effects on the Wechsler Adult Intelligence Scale-III subtests. *Archives of Clinical Neuropsychology*, *15*, 311–317.

Wechsler, D. (1939). *Measurement of Adult Intelligence.* Baltimore: Williams & Wilkins.

Wechsler, D. (1955). *Wechsler Adult Intelligence Scale.* New York: Psychological Corporation.

Wechsler, D. (1958). *The measurement and appraisal of adult intelligence* (4th ed.). Baltimore: Williams & Wilkins.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale* (Revised). San Antonio: Psychological Corporation.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale* (3rd ed.). San Antonio: Psychological Corporation.

Wechsler, D. (2002). *WAIS-III/WMS-III technical manual* (updated). San Antonio: Psychological Corporation.

Wechsler, D. (2008a). *Wechsler Adult Intelligence Scale. Administration and Scoring Manual* (4th ed.). San Antonio: Psychological Corporation.

Wechsler, D. (2008b). *Wechsler Adult Intelligence Scale. Technical and interpretive manual* (4th ed.). San Antonio: Psychological Corporation.