Psychology and Aging
1989, Vol. 4, No. 3, 307–320

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0882-7974/89/$00.75

Improving Aerobic Capacity in Healthy Older Adults Does Not Necessarily Lead to Improved Cognitive Performance

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The effects of aerobic exercise training in a sample of 85 older adults were investigated. Ss were assigned randomly to either an aerobic exercise group, a nonaerobic exercise (yoga) group, or a waiting-list control group. Following 16 weeks of the group-specific protocol, all of the older Ss received 16 weeks of aerobic exercise training. The older adults demonstrated a significant increase in aerobic capacity (cardiorespiratory fitness). Performance on reaction-time tests of attention and memory retrieval was slower for the older adults than for a comparison group of 24 young adults, and there was no improvement in the older adults' performance on these tests as a function of aerobic exercise training. Results suggest that exercise-related changes in older adults' cognitive performance are due either to extended periods of training or to cohort differences between physically active and sedentary individuals.

Several parameters of cardiovascular functioning (e.g., maximal heart rate, cardiac output, and left ventricular ejection fraction during exercise) typically exhibit a decline during later adulthood, even in the absence of overt coronary disease (Brandfonbrener, Landowne, & Shock, 1955; Gerstenblith, Lakatta, & Weisfeldt, 1976; Port, Cobb, Coleman, & Jones, 1980; Strandell, 1976). There is, in addition, a significant age-related decline in cardiorespiratory fitness (i.e., aerobic capacity), the ability to sustain maximal expenditures of energy. This decline in aerobic capacity is particularly pronounced for performances in which the maximal power output closely approximates the power available, as when, for example, maximal performance relies on the involvement of large muscle systems (Stones & Kozma, 1985).

Many aspects of cognitive performance also undergo an age-related decline; this is especially true of tasks that are attention-demanding or provide minimal environmental support for memory encoding and retrieval processes (Burke & Light, 1981; Craik & Byrd, 1982; Hasher & Zacks, 1989). Even in the presence of adequate retrieval support (e.g., memory tasks that measure performance by means of recognition rather than recall), age differences are evident in the speed of performance, and a generalized age-related slowing in the speed of information processing can account for age differences across a wide variety of cognitive tasks (Salthouse, 1985a, 1985b).

Evidence from several cross-sectional studies has suggested that aerobic capacity may be related to age-related changes in cognitive functioning. Spirduso (1975, 1980) examined simple and choice reaction time (RT) in groups of young and older adult men who were either relatively sedentary or more active physically (racquet sports enthusiasts). For both RT measures, the age-related slowing was due almost entirely to the performance of old-inactive men; the old-active men exhibited RTs near the level of the young men's RT. Using a similar classification scheme, Spirduso and Clifford (1978) reported that age differences in both between- and within-subjects variability, as well as in mean RT, were smaller in magnitude for physically active men, relative to inactive men. Rikli and Busch (1986) found that this attenuation of age differences as a function of physical activity was also evident in the choice-RT performance of women. The implication of these data is that maintaining a relatively high level of aerobic capacity either prevents or attenuates age-related slowing of information-processing speed, perhaps by maintaining the efficiency of oxygen transport in the central nervous system (McFarland, 1963; Spieth, 1965).

The most important limitation of cross-sectional data for questions regarding aerobic capacity is that relatively faster RT performance may be part of the genetic profile that leads some individuals, rather than others, to be physically active—rather than being a consequence of activity or exercise training. To establish more definitely a causal link between aerobic capacity and age differences in the speed of information processing, it would be necessary to demonstrate improvements in RT perfor-

This research was supported by Grants AG04238 and AG02163 from the National Institute on Aging and by Grant HL30675 from the National Heart, Lung, and Blood Institute.

We are grateful to Fred Cobb, Martin Sullivan, and Michael Higginbotham for ergometry testing, and to Janet Simon, Robin Pomeroy, Julia Whitaker, Cheri Rich, Sally Schnitz, Carol Cracciolo, Janet Ivey, Audrey Norman, Marti Wilson, and Tina Caldwell for technical assistance.

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mance—*within subjects*—concomitant with training-induced improvements in aerobic capacity.

Previous attempts to provide this demonstration have yielded mixed results. Although older adults' performance on various psychometric tests has been reported to improve following exercise-related increases in aerobic capacity, previous investigations have been limited by various design problems, such as the failure to include a no-exercise control group (Barry, Steinmetz, Page, & Rodahl, 1966; Elsayed, Ismail, & Young, 1980) or using only institutionalized geriatric mental patients as subjects (Powell, 1974). Dustman et al. (1984) used a design that included both an exercise control group (strength and flexibility training) and a no-exercise control group; the exercise (experimental) group participated in aerobic exercise training. All of the subjects were relatively healthy but sedentary older adults. Following a 4-month protocol, an improvement occurred both in aerobic capacity and in performance on several neuropsychological tests that was greater in magnitude for the exercise group than for either of the control groups. Dustman et al. (1984) suggested that aerobic exercise training "affects processes underlying attention and concentration" (p. 40). Blumenthal and Madden (1988), however, found that for men between 30 and 58 years of age, aerobic exercise training led to improvements in aerobic capacity but did not change subjects' performance on a RT test of short-term memory.

In view of the mixed results of previous investigations of the effects of exercise on cognitive performance and the disparate cognitive tasks that have been included previously in assessment protocols, we attempted to develop a more fine-grained analysis of the potential changes in older adults' cognitive functioning as a consequence of improved aerobic capacity. We selected two forms of memory retrieval that in previous experiments have exhibited an age-related slowing: search of short-term episodic memory (Anders, Fozard, & Lillyquist, 1972; Blumenthal & Madden, 1988) and search of long-term semantic memory (Madden, 1985). We used a secondary-task RT methodology (Kerr, 1973), which provides estimates of both the speed and attentional demands of performance. Subjects participated in a supervised program of exercise training designed to improve aerobic capacity. It was thus possible to (a) use a single RT methodology for measuring potential changes in both the speed and attentional demands of memory retrieval, and (b) assess these changes as a function of improved aerobic capacity within subjects.

Method

Design

The present assessments were part of a larger project investigating the physiological and behavioral effects of aerobic exercise training in healthy older adults (Blumenthal et al., in press). The exercise protocol involved three assessments. The older subjects completed both the short-term memory and long-term memory tasks, as well as tests of cardiorespiratory fitness, at each assessment. Time 1 was a baseline assessment that preceded the exercise training. Between Time 1 and Time 2, each older subject participated in one of three groups, an aerobic exercise group, a yoga group, or a waiting-list control group, for 16 weeks. All of the older subjects participated in aerobic exercise training for 16 weeks between Times 2 and 3. A comparison group of young adults also performed the RT tests (each subject performing both of the RT tasks), but the young adults did not participate in exercise training and were only assessed at one point in time. Thus, age differences in the present measures of cognitive functioning were examined by comparing the young adults' data with the older adults' data at Time 1. Potential changes in the older adults' performance as a function of exercise were examined by comparing the three groups of older adults across Times 1–3.

Subjects

The older adults were recruited from advertisements placed in the local media and from the Duke Aging Center Subject Register. Subjects were paid $100 for completing the exercise program. The young adults were recruited from advertisements posted on the Duke campus and were paid $14 for their participation.

Screening criteria. Screening included medical history, physical examination, and bicycle ergometry exercise, testing performed under continuous electrocardiographic (ECG) monitoring. Individuals with uncontrolled hypertension, diabetes, or coronary heart disease were excluded from the study. Individuals who were taking either beta blockers or psychotropic medication regularly were also excluded. Approximately one half of the subjects who completed the Time-1 assessment were taking diuretics, hormone replacements, or over-the-counter medication regularly. Exercise testing followed the ACSM (American College of Sports Medicine, 1986) guidelines. A cardiologist and either an exercise physiologist or nurse clinician were present for all of the exercise tests. All of the subjects were judged to be free of any medical condition that would preclude a program of either aerobic exercise or yoga. Subjects' personal physicians were notified, and subjects provided written informed consent.

In all, 101 older subjects completed the Time-1 assessments. The data of 16 of these subjects were eliminated because of excessively high error rates at Time 1; the final sample of older adults at Time 1 thus included 85 individuals (44 men, 41 women). Of these subjects, 79 (40 men, 39 women) completed all three assessments. The 6 dropouts included 3 from the aerobic group, 2 from the yoga group, and 1 from the wait group.

Age, education, and psychometric performance. The characteristics of the subjects are presented in Table 1. The young adults (12 men, 12 women) ranged between 18 and 28 years of age. The 85 older adults who completed the Time-1 assessment ranged between 60 and 83 years of age. At Time 1, the mean raw score on the Digit Symbol subtest of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1981) was 27 points higher for young adults than for older adults, $F(1, 105) = 176.85$, $p < .0001$. The two age groups did not differ significantly in years of education, although the mean raw score on the WAIS Vocabulary subtest favored the young adults by 5 points, $F(1, 105) = 8.91$, $p < .01$.

Univariate analyses of variance (ANOVAS) were also performed on years of age and education and WAIS Digit Symbol and Vocabulary raw scores for the 79 older adults who completed all three assessments. These ANOVAS included exercise group (aerobic, yoga, wait) and gender as between-subject variables. None of these analyses yielded any significant main effects or interactions.

Group assignment. Each older adult was assigned randomly to either the aerobic group (11 women, 14 men), yoga group (14 women, 14 men), or wait group (14 women, 12 men). The groups differed in their activities in the 16 weeks between Times 1 and 2. Subjects in the aerobic group attended three supervised exercise sessions per week. On the basis of maximum heart rate achieved during the initial (Time 1) bicycle exercise test, each subject was provided with a 6-bpm (beats per minute) training range equivalent to 70% maximum heart rate reserve (Karvo-

Table 1
Characteristics of Subjects and Groups at Times 1–3

Variable	Age[a]	Education[a]	WAIS Digit symbol	WAIS Vocabulary
		Subjects at Time 1		
Young (n = 24)				
M	21.88	14.75	75.84	65.66
SD	3.19	2.01	7.68	8.92
Older (n = 85)				
M	66.98	15.31	48.85	60.57
SD	4.49	2.51	8.96	6.90
		Groups of older adults completing Times 1–3		
Aerobic (n = 25)				
M	66.52	15.12	51.28	61.24
SD	4.07	2.06	9.54	6.50
Yoga (n = 28)				
M	68.04	15.68	47.29	61.22
SD	5.42	2.54	8.78	7.49
Wait (n = 26)				
M	66.62	14.92	47.96	59.88
SD	3.54	2.97	8.81	6.87

Note. WAIS Digit Symbol and Vocabulary are raw scores on subtests of the Wechsler Adult Intelligence Scale (Wechsler, 1981).
[a] In years.

nen, Kentala, & Mustala, 1957). Each aerobic exercise session began with a 10-min period of warm-up exercises, which was followed by 30 min of continuous bicycle ergometry at an intensity that would maintain heart rate within the assigned training range. Subjects then performed brisk walking and/or jogging for 15 min, again maintaining heart rate within the training range. During this latter 15-min interval, subjects were allowed to supplement their walking with 5 min of arm ergometry. The exercise session concluded with 5 min of cool-down exercises. Heart rates were monitored via radial pulses and were recorded, along with rating of perceived exertion (Borg, 1982), three times during the 45-min aerobic portion of each exercise session.

Subjects in the yoga group participated in 60 min of supervised yoga exercises twice a week between the Time-1 and Time-2 assessments. The yoga classes provided a control for the effects of social stimulation and attention from trainers, without producing an aerobic training stimulus.

Subjects assigned to the wait group did not receive any form of treatment between the Time-1 and Time-2 assessments. These subjects were instructed specifically to not change their physical activity habits and to not engage in any aerobic exercise during the intervening 16 weeks. Subjects in all three groups were also instructed to maintain their regular dietary habits until completion of the study. No suggestions for dietary modification were offered.

Following the Time-2 assessment, subjects from all of the groups participated in aerobic exercise training, identical to that designed initially for the aerobic group, for 16 weeks. The Time-3 assessments were given at the completion of this subsequent 16-week interval.

Compliance with the aerobic exercise and yoga protocols was 90% or greater for both men and women.

Physiological and Cognitive Assessments

Each of the three assessments included both physiological measures of aerobic capacity and RT measures of cognitive functioning. The physiological measures were obtained on a separate day from the cognitive measures, and neither type of measure was obtained on an exercise-training day.

Aerobic capacity. The measure of aerobic capacity was obtained from bicycle ergometry testing. At each assessment, each subject performed an initial practice test and a maximum-effort exercise test on a Fitron cycle ergometer (Cybex Lumex, Inc.). The graded exercise protocol consisted of successive 3-min stages, starting at 150 kpm and increasing 150 kpm at each stage. Subjects maintained a pedaling rate of 50 rpm and exercised until exhaustion or standard clinical endpoints. A 12-lead ECG (Hewlett Packard, Inc.) provided continuous electrocardiographic monitoring. Heart rate was recorded every minute, and blood pressure was measured by cuff sphygmomanometry at 3-min intervals. Measurements of respiratory function and oxygen consumption were obtained by means of a System 4400 metabolic system (Alpha Technologies, Inc.).

Reaction-time tasks. Subjects performed two RT tasks, one involving primarily short-term or working memory processes (letter search) and one involving long-term memory processes (word comparison). Several aspects of procedure were common to the two tasks. Each was a secondary-task paradigm in which subjects performed concurrently a *yes/no* choice response to a visual stimulus (the primary task) and a simple response to an auditory stimulus (the secondary task). Subjects made their responses in the primary task with the index and middle fingers of the dominant hand. Responses to the tone were made with the index finger of the nondominant hand.

The secondary-task methodology assumes that the primary and secondary tasks compete for a limited pool of attentional capacity or processing resources (Kantowitz, 1985; Kerr, 1973). Increases in secondary-task RT thus represent increases in the attentional demands of the primary task. Adult age differences in this secondary-task measure of attentional demand, as well as in the speed of performance (i.e., primary-task RT), have been obtained consistently (Craik & McDowd, 1987; Guttentag & Madden, 1987; Madden, 1986).

The presentation of the stimuli and measurement of subjects' responses were controlled by an Apple II microcomputer. The tone was a nonsinusoidal, 213-ms tone generated by the microcomputer and presented via a loudspeaker internal to the microcomputer at approximately 60 dB. Primary-task stimuli were presented on the microcomputer screen. The two response keys for the primary task were adjacent to each other on one side of the microcomputer keyboard, and the response key for the secondary task was located on the opposite side of the keyboard. The side of the keyboard containing the primary-task response keys was matched to the subject's dominant hand.

Subjects performed the letter-search and word-comparison tasks on 2 consecutive days. Each testing session was devoted to one of the tasks and was approximately 90 min in duration. Within each age group, the assignment of either the letter-search or word-comparison task to the first testing session was alternated across subjects. Whether the *yes* response in the primary task was assigned to the index or middle finger of the dominant hand was also alternated across subjects. For each subject, this assignment of the *yes* response was held constant across the letter-search and word-comparison tasks. The older subjects retained the same *yes*-response assignment across the three assessment periods.

The two memory tasks each included 216 test trials, 144 containing both a tone and visual display (tone-present trials) and 72 on which only a visual display (tone-absent trials) was presented. The tone could appear at one of three temporal locations relative to the visual display. These locations are defined by the stimulus onset asynchrony (SOA) between the tone and the display. At the −400-ms SOA, the onset of the tone preceded the onset of the display by 400 ms. At the 100-ms and 600-ms SOAs, the onset of the tone followed the onset of the display by these values.

Subjects were instructed to devote most of their attention to the primary task and to "protect" their primary-task performance if they encountered interference from the tone on the dual-task trials. Each testing session began with a block of 30 baseline simple-RT trials on which only tones, and no visual displays, were presented. Following this block of baseline trials, subjects were given one block of dual-task practice trials that resembled the test trials to be presented (i.e., letter search or word comparison). Subjects then performed six blocks of 36 test trials. Each block was a randomized sequence of 24 tone-present trials and 12 tone-absent trials. The session ended with a second block of 30 baseline simple-RT trials.

Letter-search task. The letter-search task, a version of Sternberg's (1966) paradigm, required subjects to compare a visually presented probe letter with a set of letters held in memory. On each trial, a memory set of either two, four, or six letters (consonants) was assigned, and subjects made a *yes/no* response regarding whether the probe letter was a member of the memory set. Subjects' primary-task RTs for letter search provided information regarding the duration of different information-processing stages of short-term memory. Because the increase in subjects' mean RT in this task is typically a linear function of the number of items in the memory set, the slope of this function is considered an estimate of the average time required for the comparison between the probe and each item in the current memory set (i.e., the average increase in RT associated with each additional memory-set item). The zero-intercept of the linear function represents the duration of the other processing components not involved in memory comparison per se, such as the identification of the probe letter and selection of a response (Sternberg, 1975).

The memory set to be used on the upcoming trial was listed at the top of the microcomputer viewing screen. Subjects viewed the memory set for as long as they wished. Pressing the space bar on the keyboard erased the memory set and brought a single probe letter to the screen; the probe remained in view until the subject pressed one of the *yes* or *no* response keys. The tone SOAs were relative to the onset of the probe letter. A new memory set was assigned at the beginning of each trial.

Each memory set was composed of either two, four, or six different letters. Within each trial block, there were six trials for each combination of response type and set size. These six trials contained four tone-present trials (at least one with each SOA value) and two tone-absent trials. Across trial blocks, each SOA value was associated eight times with each combination of set size and response type.

Two different stimulus lists were alternated across subjects within each age group at Time 1 and (for older subjects) across testing sessions. Two different orders of the trial blocks were alternated across lists and subjects.

Word-comparison task. The word-comparison task required subjects to make a decision regarding the synonymy of two words. On each trial, two words were presented visually and subjects made a *yes/no* response regarding whether the two words "have approximately the same meaning." To reduce the influence of the physical similarity of the words on subjects' decisions, the displays always contained one uppercase and one lowercase word. There were three types of displays, two of which required a *yes* response and one of which required a *no* response. On the *yes*-response trials, the display words could be either identical (e.g., MODEL/model) or synonyms (e.g., TOTAL/sum). On the *no*-response trials, the display words were unrelated semantically (e.g., DARE/palace).

The primary-task RTs in this paradigm provide information regarding retrieval from long-term memory. For the identical display words, subjects can make a *yes* decision without necessarily accessing the meaning of the display items; because the two items contain the same sequence of letters, they must represent the same word. For the synonym displays, however, in which the two words contain different sequences of letters, it is necessary to retrieve the meaning of the words to reach a *yes* decision. Thus, the RT difference between the identical and synonym displays is an estimate of the time required for long-term memory retrieval in this task (Madden, 1985).

Within each trial block, there were 12 instances of each of the three display types (identical, synonym, and unrelated). Of these, 8 were tone-present trials (at least 2 for each SOA value) and 4 were tone-absent trials. Across trial blocks, each SOA value was associated 16 times with each of the identical, synonym, and unrelated displays.

The display words were drawn from a pool of 432 word pairs (144 synonymous, 144 identical, and 144 unrelated). The three display types were equated for word length and normative frequency. The synonym pairs were drawn from the Whitten, Suter, and Frank (1979) norms; each pair possessed a synonymy rating of greater than 4 on a 7-point scale (M = 5.96, SD = 0.43). The complete pool of word pairs was divided into two separate lists of 216 word pairs each (72 per display type). The two lists (and two block orders) were alternated across subjects and assessments as in the letter-search task.

Results

Age Differences in Letter Search at Time 1

Primary task. Subjects' mean RTs and error rates in the letter-search primary task, for the first assessment (Time 1), are presented in Figure 1. *Yes* and *no* responses were averaged. Preliminary analyses of RT data demonstrated that the increase in RT over set size was 99% linear.

In view of this linearity, subsequent analyses were performed on the slope and intercept of the linear RT functions obtained for each subject individually. This analysis, which included age group and gender as between-subjects variables, indicated that a significant age-related increase was present both for the slope values, $F(1, 105) = 3.90$, $p < .05$, and for the intercept values, $F(1, 105) = 39.75$, $p < .0001$. The mean slope and intercept of each age group's RT function are presented in Figure 1.

The mean percentage error in the letter-search primary task was 6.46% for older adults and 4.30% for young adults.

Secondary task. The analysis of subjects' RT performance in the secondary task, tone detection, used tone-RT minus the baseline simple-RT as the dependent variable. The baseline simple-RT was the mean of the simple-RT trials given at the beginning and end of the letter-search testing session. This baseline was not significantly different for the two age groups (young adults = 222 ms, older adults = 229 ms).

The tone-RT data for the letter-search task at Time 1 are presented in Figure 2. The ANOVA of these data included age group and gender as between-subjects variables, and set size and SOA as within-subjects variables. Tone-RT increased as a function of age, $F(1, 105) = 72.13$, $p < .0001$, and set size, $F(2, 210) = 191.08$, $p < .0001$, and varied across the three SOAs, $F(2, 210) = 57.95$, $p < .0001$.

Three interactions were significant in the tone-RT data: Age × SOA, $F(2, 210) = 5.48$, $p < .01$; Set Size × SOA, $F(4, 420) = 7.25$, $p < .0001$; and Age × Set Size, $F(2, 210) = 4.81$, $p < .01$. The Age × SOA effect occurred because age differences in tone-RT were greatest in magnitude at the −400-ms SOA. The Set Size × SOA interaction occurred because the increase in tone-RT as a function of set size was more pronounced at the 100-ms SOA than at either the −400-ms or 600-ms SOAs. The

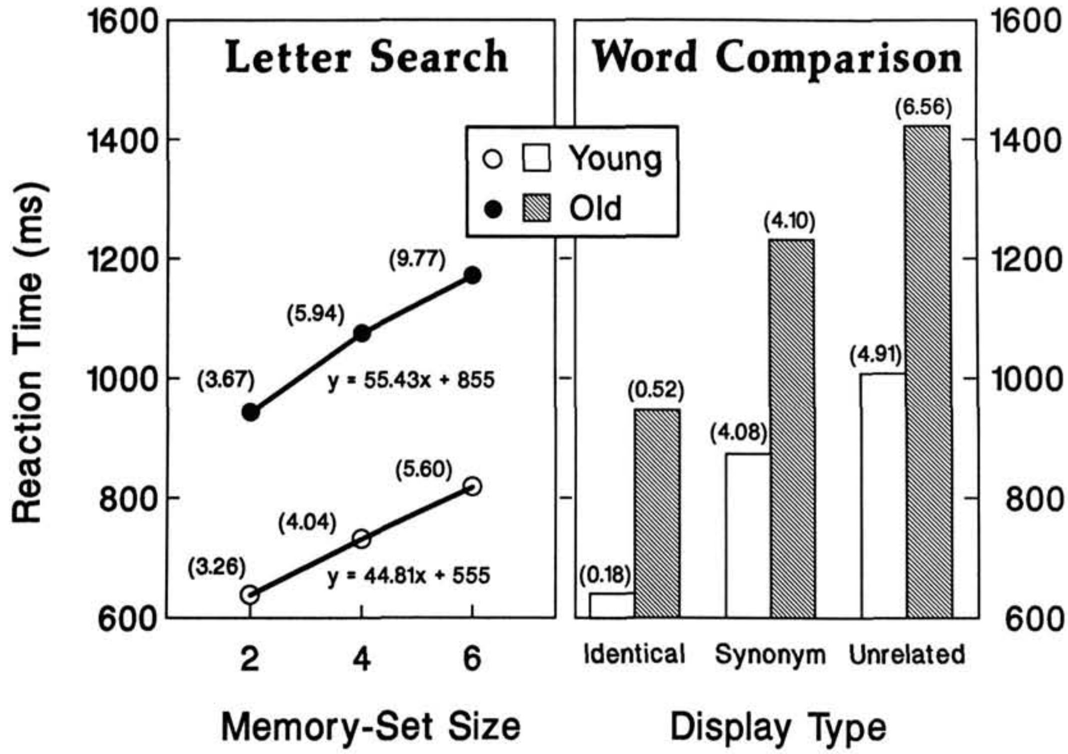

Figure 1. Mean primary-task reaction time in the letter-search and word-comparison tasks as a function of age group, memory-set size (letter search), and display type (word comparison) at Time 1. (The mean percentage error associated with each experimental condition is given in parentheses. For the letter-search task, the least-squares estimate of the linear set-size function is also presented for each age group.)

Age × Set Size interaction represents an increase in the magnitude of the age difference as a function of increasing set size.

The mean percentage of tone detection misses was 1.72% for the older adults and 0.55% for the young adults. The false-alarm rate on tone-absent trials was 2.61% for young adults and 1.22% for older adults.

Age Differences in Word Comparison at Time 1

Primary task. The mean RTs and error rates in the word-comparison primary task for Time 1 are presented in Figure 1. Because the estimate of memory retrieval in this task (the difference between identical and synonym trials) is specific to the *yes*-response trials, only the analyses of the *yes* responses are reported. The ANOVA of the *yes*-response RTs included age group and gender as between-subjects variables, and display type (identical, synonym) and the presence versus the absence of the tone as within-subjects variables. This ANOVA yielded significant main effects for age, $F(1, 105) = 60.73$, $p < .0001$, and display type, $F(1, 105) = 367.53$, $p < .0001$. Mean RT was 332 ms higher for older adults than for young adults and was 274 ms higher for synonym displays than for identical displays. The interactions of Age × Tone Presence, $F(1, 105) = 5.79$, $p < .05$; Display Type × Tone Presence, $F(1, 105) = 12.03$, $p < .001$; and Age × Display Type, $F(1, 105) = 3.81$, $p < .05$, were also significant. The interactions involving tone presence represent a relatively greater RT slowing, associated with the tone, for older adults (23 ms) compared with young adults (15 ms) and for identical displays (26 ms) compared with synonym displays (2 ms). The Age × Display Type effect occurred because the increase in RT for the synonym displays, relative to the identical displays, was greater for the older adults (285 ms) than for the young adults (233 ms).

The mean error rate on the *yes*-response trials was 2.13% for young adults and 2.31% for older adults.

Secondary task. The mean baseline simple-RT values for the word-comparison task were not significantly different for the two age groups (young adults = 208 ms, older adults = 227 ms). The mean values for the secondary-task tone RT measure at Time 1 are presented in Figure 2. In the ANOVA of the tone-RT measure on the *yes*-response trials, all of the main effects were significant: age, $F(1, 105) = 64.26$, $p < .0001$; gender, $F(1, 105) = 5.80$, $p < .05$; display type, $F(1, 105) = 89.65$, $p < .0001$; and SOA, $F(2, 210) = 31.78$, $p < .0001$. The tone-RT measure was 422 ms higher for older adults than for young adults, 170 ms higher for women than for men, and 147 ms higher for synonym displays than for identical displays. The tone RT varied from 602 ms at the −400-ms SOA, to 828 ms at the 100-ms SOA, and 539 ms at the 600-ms SOA.

On the *yes*-response trials, the interactions for tone-RT were SOA × Display Type, $F(1, 105) = 22.71$, $p < .0001$; Age × Dis-

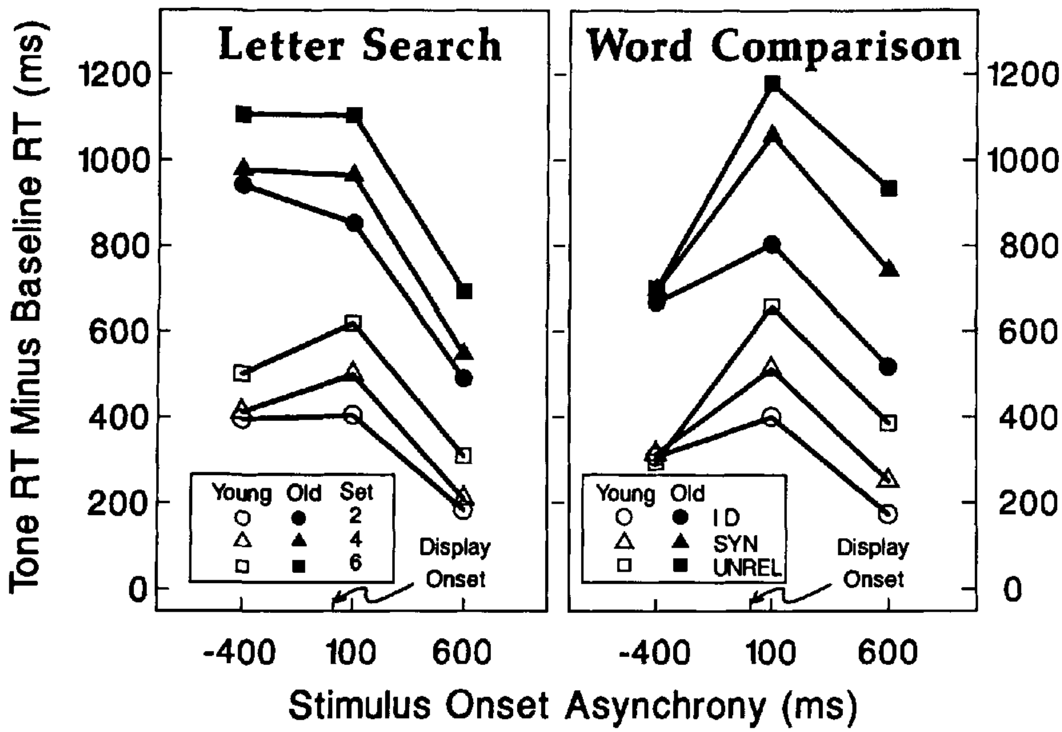

Figure 2. Mean secondary-task reaction time (minus reaction time on the baseline trials) in the letter-search and word-comparison tasks as a function of age group, the stimulus onset asynchrony between the tone and the display, memory-set size (letter search), and display type (word comparison) at Time 1.

play Type, $F(1, 105) = 18.15$, $p < .0001$; and Age × SOA × Display Type, $F(2, 210) = 3.71$, $p < .05$. The SOA × Display Type effect represents the fact that the increase in tone-RT associated with the synonym displays was significant only at the two SOAs following the onset of the display, and not at the −400-ms SOA. The Age × Display Type effect occurred because the age difference in tone-RT was greater in magnitude for the synonym displays (475 ms) than for the identical displays (370 ms). The three-way interaction can be viewed as a variation in the age differences in tone-RT as a function of display type and SOA. For both display types, age differences were greater at the 100-ms SOA (i.e., immediately following display onset) than at the other SOAs, but this pattern was more pronounced for the synonym displays than for the identical displays.

On the *yes*-response trials, the miss rate in tone detection did not exceed 1.06% for either age group; the false-alarm rate was 2.25% for the young adults and 1.62% for the older adults.

Effects of Exercise on Aerobic Capacity

The changes in the older adults' aerobic capacity across Times 1–3 were represented by the measure of maximal oxygen consumption ($VO_{2\,max}$) obtained from the bicycle ergometry tests. The mean $VO_{2\,max}$ values are presented in Table 2. (Because of equipment problems, data for 2 subjects, 1 in the aerobic group and 1 in the wait group, were lost.) The ANOVA of the $VO_{2\,max}$ values included gender and exercise group as between-subject variables and time as a within-subjects variable. The main effects of gender, $F(1, 71) = 89.93$, $p < .0001$, and time, $F(2, 142) = 11.56$, $p < .001$, were significant. Mean $VO_{2\,max}$ was 6.80 ml/kg/min higher for men than for women, and increased from 19.18 ml/kg/min at Time 1, to 19.63 ml/kg/min at Time 2, and 20.83 ml/kg/min at Time 3.

The Time × Group interaction $F(4, 142) = 2.91$, $p < .05$, was also significant. Aerobic capacity remained constant for the yoga and wait groups between Times 1 and 2, whereas the 11.02% increase in $VO_{2\,max}$ for the aerobic group was significant, $F(1, 22) = 11.09$, $p < .01$. Between Times 2 and 3 the main effect of time was significant, $F(1, 71) = 10.66$, $p < .01$, representing a further average increase in $VO_{2\,max}$ of 6.11%, but the Time × Group interaction was not significant for these two assessments. For the three groups combined, the average increase in $VO_{2\,max}$ from Time 1 to Time 3 was 8.59%.

Effects of Exercise on Letter Search

Primary task. The older adults' RT and error data from the letter-search primary task for Times 1–3 are presented in Table 3. The ANOVA of the slope values included gender and exercise group as between-subjects variables and time as a within-subjects variable. This ANOVA yielded only a gender main effect, $F(1, 73) = 4.12$, $p < .05$, with the mean slope value of the women (59.98 ms) exceeding that of the men (51.39 ms). For the intercepts, only the time main effect, $F(2, 146) = 11.57$, $p < .0001$, was significant. The mean intercept value decreased

Table 2
Maximal Oxygen Uptake ($VO_{2\,max}$) and Baseline Simple-RT as a Function of Exercise Group and Time of Assessment

	Group		
Variable	Aerobic (n = 25)	Yoga (n = 28)	Wait (n = 26)
	$VO_{2\,max}$		
Time 1			
M	19.69	18.79	19.13
SD	3.29	3.50	2.93
Time 2			
M	21.86	18.64	18.58
SD	3.29	3.74	2.62
Time 3			
M	21.86	19.96	20.80
SD	4.10	4.0	3.61
	Simple-RT (letter search)		
Time 1			
M	239	234	214
SD	66	43	27
Time 2			
M	221	232	211
SD	53	53	30
Time 3			
M	229	224	212
SD	66	52	37
	Simple-RT (word comparison)		
Time 1			
M	240	233	213
SD	68	62	34
Time 2			
M	223	236	210
SD	65	50	39
Time 3			
M	225	220	212
SD	51	53	32

Note. $VO_{2\,max}$ values are in ml/kg/min, and RT values are in milliseconds.

from 853 ms at Time 1, to 817 ms at Time 2, and 782 ms at Time 3.

The mean error rate varied from 4.78% to 6.10% across the three exercise groups and decreased from 6.22% at Time 1, to 5.25% at Time 2, and 4.69% at Time 3.

Secondary task. The baseline simple-RTs for the letter-search task are presented in Table 2. The ANOVA of these values did not yield any significant main effect or interaction. The secondary-task RTs (tone-RT minus baseline RT) for letter search are presented in Table 4. Gender and exercise group were between-subjects variables; time, set size, and SOA were within-subjects variables. Tone-RT increased significantly as a function of set size, $F(2, 146) = 416.68, p < .0001$, and varied across the three SOAs, $F(2, 146) = 138.72, p < .0001$.

The interactions of Set Size × SOA, $F(4, 292) = 14.05, p < .0001$, and Time × SOA, $F(4, 292) = 4.92, p < .001$, were significant in the tone-RT data. The effect of set size was significant at all three SOAs ($F > 25.0$, in each case), but was most pronounced at the 100-ms SOA. The interaction of time and SOA occurred because tone-RT at the −400-ms SOA did not vary significantly across time, whereas tone-RT decreased at each successive assessment for both the 100-ms SOA and the 600-ms SOA.

Miss rates for secondary-task performance are also presented in Table 5. The average miss rate did not exceed 1.50% for any of the exercise groups. The mean false-alarm rate on the tone-absent trials varied from 2.04% to 2.78% across the three groups.

Effects of Exercise on Word Comparison

Primary task. Mean RT and error rate in the word-comparison task for Times 1–3 are presented in Table 5. In the ANOVA of primary-task mean RT on the *yes*-response trials, gender and exercise group were between-subjects variables; display type (identical versus synonym), tone presence, and time were within-subjects variables. This ANOVA yielded significant main effects of display type, $F(1, 73) = 983.19, p < .0001$; tone presence, $F(1, 73) = 3.95, p < .05$; and time, $F(2, 146) = 14.93, p < .0001$. Primary-task RT was 289 ms higher for synonym displays than for identical displays and was 13 ms higher on tone-present trials than on tone-absent trials. Mean RT decreased from 1,096 ms at Time 1, to 1,055 ms at Time 2, and 1,028 ms at Time 3. The only interaction that was significant in these data was the Display Type × Tone Presence effect, $F(1, 73) = 13.11, p < .001$, which occurred because the RT increase associated with the tone was greater for identical displays (24 ms) than for synonym displays (2 ms).

The mean error rate on the *yes*-response trials varied from 1.98% to 2.36% across the three exercise groups. The error rate decreased from 2.37% at Time 1, to 2.21% at Time 2, and 1.76% at Time 3.

Secondary task. The baseline simple-RTs for the word-comparison task for Times 1–3 are presented in Table 2; an analysis of these data did not yield any significant effects. The secondary-task tone-RT values (minus baseline RTs) and miss rates are presented in Table 6. In the analysis of the tone-RT values on the *yes*-response trials, gender and exercise group were between-subjects variables; time, display type, and SOA were within-subjects variables. The ANOVA yielded significant main effects of display type, $F(1, 73) = 399.49, p < .0001$; SOA, $F(2, 146) = 48.78, p < .0001$; and gender $F(1, 73) = 4.68, p < .05$. The tone-RT measure was 187 ms higher for synonym displays than for identical displays, 133 ms higher for women than for men, and varied from 781 ms at the −400-ms SOA, to 918 ms at the 100-ms SOA, and 586 ms at the 600-ms SOA.

The interactions of SOA × Display Type, $F(2, 146) = 66.31, p < .0001$; Time × Gender, $F(2, 146) = 5.17, p < .01$; Time × Display Type, $F(2, 146) = 3.73, p < .05$; Time × SOA, $F(4, 292) = 18.04, p < .0001$; and Time × SOA × Display Type, $F(4, 292) = 3.74, p < .01$, were significant. The interaction of SOA × Display Type occurred because the magnitude of the RT difference between the identical and synonym displays was greatest at the 100-ms SOA. The interactions involving time represent relatively small fluctuations in the other variables across the three assessments.

Table 3
Primary-Task Reaction Time (RT) and Error Rate (err) for Letter Search as a Function of Exercise Group, Time of Assessment, Set Size, and Tone Presence

	Set size							
	2 Tone		4 Tone		6 Tone			
Variable	Presence	Absence	Presence	Absence	Presence	Absence	Slope	Intercept
			Aerobic group (n = 25)					
Time 1								
RT								
M	964	929	1097	1059	1216	1159	61.53	835
SD	269	228	271	234	271	221	26.13	275
err								
M	4.39	2.18	5.48	5.50	9.80	6.0		
SD	3.14	2.45	3.10	5.45	5.09	4.54		
Time 2								
RT								
M	907	861	1036	1022	1133	1115	58.35	786
SD	230	197	225	197	223	209	23.39	240
err								
M	3.66	1.51	3.81	4.52	8.06	5.34		
SD	2.72	3.23	4.22	4.40	5.50	4.78		
Time 3								
RT								
M	873	851	1008	996	1114	1092	60.20	753
SD	230	205	217	217	231	221	25.09	236
err								
M	1.59	0.84	3.98	3.34	7.88	8.17		
SD	2.04	1.66	3.05	4.21	3.73	6.87		
			Yoga group (n = 28)					
Time 1								
RT								
M	945	893	1074	1041	1149	1116	52.07	838
SD	214	220	248	220	250	239	23.27	211
err								
M	4.75	2.09	7.28	6.26	10.54	10.71		
SD	3.64	3.07	4.88	5.55	5.54	5.78		
Time 2								
RT								
M	934	894	1055	1002	1142	1115	52.70	823
SD	249	251	246	231	255	256	24.28	257
err								
M	4.00	2.09	6.31	5.21	10.16	9.08		
SD	3.58	3.72	4.53	5.18	7.24	6.52		
Time 3								
RT								
M	905	861	1019	1020	1102	1094	51.58	798
SD	234	211	237	233	247	228	20.34	231
err								
M	3.11	1.20	4.75	4.47	9.81	7.90		
SD	2.43	2.26	4.86	3.60	5.54	6.60		
			Wait group (n = 26)					
Time 1								
RT								
M	1012	919	1144	1053	1224	1155	54.51	887
SD	197	131	199	138	201	176	24.97	188
err								
M	4.06	3.37	4.79	5.62	8.95	9.77		
SD	3.05	4.31	2.99	4.47	5.96	6.90		
Time 2								
RT								
M	958	907	1083	1063	1177	1147	55.92	841
SD	159	145	163	142	190	178	19.11	147
err								
M	2.63	0.65	5.58	4.0	8.72	8.49		
SD	2.66	1.52	4.36	5.0	3.79	6.74		
Time 3								
RT								
M	906	856	1046	1002	1120	1099	55.19	794
SD	141	125	168	152	169	165	22.36	140
err								
M	1.92	1.12	3.83	4.50	8.16	7.54		
SD	2.31	2.77	3.18	3.72	5.38	5.37		

Note. Reaction-time values are in milliseconds, and error rates are percentages.

Table 4
Secondary-Task Reaction Time (RT) and Error Rate (err) for Letter Search as a Function of Exercise Group, Time of Assessment, Set Size, and the Stimulus Onset Asynchrony (SOA) Between the Tone and the Probe

	Set size								
	2 SOA			4 SOA			6 SOA		
Variable	−400	100	600	−400	100	600	−400	100	600
Aerobic group (n = 25)									
Time 1									
RT									
M	962	831	457	973	935	492	1087	1122	689
SD	436	216	181	508	215	196	516	232	231
err									
M	1.49	1.24	0.50	0.75	0.50	0.74	2.24	1.49	0.74
SD	3.30	3.04	0.09	2.69	1.75	2.36	4.69	3.11	2.03
Time 2									
RT									
M	902	775	389	971	916	460	1045	1018	591
SD	409	236	175	487	229	224	504	208	177
err									
M	0.25	0.99	0.25	0.25	0.50	0.25	1.24	0.99	0.74
SD	0.07	2.21	0.07	0.07	1.75	0.07	2.78	2.21	2.03
Time 3									
RT									
M	979	753	348	1083	887	427	1165	993	594
SD	435	272	201	457	266	206	500	244	253
err									
M	1.24	0.74	0.50	1.24	0.25	0.0	1.24	0.74	0.25
SD	2.45	0.11	0.10	3.13	0.07	0.0	3.13	2.08	0.07
Yoga group (n = 28)									
Time 1									
RT									
M	951	849	471	1004	970	550	1121	1068	667
SD	465	270	200	494	298	247	514	256	263
err									
M	1.78	1.55	1.11	3.56	2.13	0.67	4.01	0.89	2.0
SD	4.53	2.78	2.45	6.21	3.82	2.50	6.76	2.15	3.70
Time 2									
RT									
M	865	822	452	911	953	521	1036	1061	670
SD	472	289	183	495	278	191	532	250	243
err									
M	1.33	1.33	1.11	0.67	0.66	0.89	2.0	2.22	1.78
SD	3.03	2.64	2.99	0.13	1.96	2.64	3.88	4.60	3.30
Time 3									
RT									
M	868	763	403	926	888	476	1005	1004	597
SD	504	269	203	551	302	215	543	279	251
err									
M	0.66	1.77	0.66	0.22	2.0	0.22	1.55	0.89	0.66
SD	1.96	3.36	1.96	0.06	5.29	0.06	3.26	2.25	1.96
Wait group (n = 26)									
Time 1									
RT									
M	946	860	536	989	1001	598	1140	1136	734
SD	431	230	190	471	230	229	421	277	203
err									
M	1.67	2.39	1.91	2.63	1.43	0.72	3.35	1.19	1.43
SD	2.77	3.57	2.89	4.45	2.95	2.01	5.31	2.50	2.71
Time 2									
RT									
M	994	886	481	1039	992	562	1207	1090	715
SD	432	268	203	440	258	243	430	262	262
err									
M	0.48	0.72	0.72	0.95	0.24	0.48	1.43	1.43	0.48
SD	1.72	2.04	2.04	0.11	0.07	0.09	2.71	3.09	0.09
Time 3									
RT									
M	1075	801	459	1124	947	508	1275	1069	645
SD	433	201	165	465	247	192	489	226	217
err									
M	0.48	0.0	0.0	0.24	0.72	0.0	1.67	1.20	0.0
SD	0.09	0.0	0.0	0.06	2.01	0.0	2.83	0.19	0.0

Note. Reaction time values and SOAs are in milliseconds, and error rates are percentages.

Table 5
Primary-Task Reaction Time (RT) and Error Rate (err) for Word Comparison as a Function of Exercise Group, Time of Assessment, Display Type, and Tone Presence

	Display type					
	Identical tone		Synonym tone		Unrelated tone	
Variable	Presence	Absence	Presence	Absence	Presence	Absence
			Aerobic group (n = 25)			
Time 1						
RT						
M	970	937	1235	1221	1441	1401
SD	235	213	300	264	256	211
err						
M	0.74	0.50	3.81	4.67	8.81	5.18
SD	1.03	1.41	3.0	5.65	6.19	5.50
Time 2						
RT						
M	922	909	1223	1261	1398	1430
SD	196	155	259	217	239	237
err						
M	0.58	0.0	4.64	2.67	4.73	1.84
SD	1.30	0.0	3.53	3.03	3.68	2.95
Time 3						
RT						
M	888	893	1196	1195	1344	1370
SD	167	151	235	220	220	223
err						
M	0.33	0.17	3.57	2.35	4.49	1.0
SD	0.73	0.04	2.61	2.78	4.15	2.19
			Yoga group (n = 28)			
Time 1						
RT						
M	986	959	1269	1263	1483	1476
SD	212	204	232	213	242	246
err						
M	0.66	0.15	4.15	3.87	9.13	5.36
SD	1.51	0.56	4.09	3.57	7.14	5.87
Time 2						
RT						
M	938	908	1216	1193	1388	1387
SD	203	175	233	219	242	214
err						
M	0.96	0.0	3.33	4.91	6.01	3.88
SD	1.46	0.0	3.24	4.49	4.97	3.76
Time 3						
RT						
M	912	893	1190	1178	1371	1395
SD	195	166	220	223	229	228
err						
M	0.07	0.45	2.54	2.69	3.85	3.73
SD	0.28	1.33	2.51	3.12	4.11	3.70
			Wait group (n = 26)			
Time 1						
RT						
M	951	919	1221	1205	1392	1383
SD	173	171	202	174	213	206
err						
M	0.24	0.97	3.75	4.98	7.91	4.01
SD	0.04	1.78	3.28	3.72	6.38	4.32
Time 2						
RT						
M	889	856	1165	1181	1345	1336
SD	132	119	180	174	161	181
err						
M	0.24	0.32	4.55	4.17	3.67	2.41
SD	0.67	0.06	2.96	4.38	3.38	3.14
Time 3						
RT						
M	881	846	1124	1133	1326	1319
SD	132	119	180	174	161	181
err						
M	1.04	0.97	3.35	3.70	4.15	2.74
SD	2.15	2.07	4.08	4.37	3.28	3.25

Note. Reaction-time values are in milliseconds and error rates are percentages.

Table 6
Secondary-Task Reaction Time (RT) and Error Rate (err) for Word Comparison as a Function of Exercise Group, Time of Assessment, Display Type, and the Stimulus Onset Asynchrony (SOA) Between the Tone and the Display

	Display type								
	Identical SOA			Synonym SOA			Unrelated SOA		
Variable	−400	100	600	−400	100	600	−400	100	600
				Aerobic group (n = 25)					
Time 1									
RT									
M	634	781	503	620	1006	718	629	1146	909
SD	349	303	261	384	344	331	420	327	304
err									
M	0.75	0.74	0.50	0.99	1.24	0.99	3.23	2.24	1.74
SD	2.59	2.08	1.75	2.21	3.04	2.36	4.15	4.38	2.91
Time 2									
RT									
M	808	808	463	899	1077	693	951	1227	903
SD	455	282	250	566	350	325	622	310	344
err									
M	0.25	0.25	0.25	0.74	0.25	0.99	2.24	0.99	0.0
SD	0.93	0.93	0.93	2.08	0.07	0.13	3.79	2.36	0.0
Time 3									
RT									
M	836	752	402	999	1042	638	1055	1222	796
SD	416	201	206	568	281	258	644	268	276
err									
M	1.0	0.50	0.50	0.0	0.75	0.50	0.74	0.74	0.25
SD	2.84	0.10	1.75	0.0	2.59	0.10	0.11	2.03	0.07
				Yoga group (n = 28)					
Time 1									
RT									
M	680	848	535	735	1104	767	718	1235	988
SD	422	305	210	530	288	236	536	349	285
err									
M	0.44	0.89	0.22	1.34	2.44	1.33	4.45	3.55	2.89
SD	1.66	2.15	0.0	1.81	4.73	3.13	8.22	4.28	4.23
Time 2									
RT									
M	708	788	482	770	1009	718	801	1194	884
SD	430	293	198	513	369	286	556	383	322
err									
M	0.66	0.44	0.22	0.66	0.44	1.11	1.55	2.22	0.89
SD	1.66	0.83	0.0	1.96	1.13	3.48	2.67	3.79	2.25
Time 3									
RT									
M	687	756	421	777	982	667	780	1127	825
SD	491	276	166	598	340	238	669	345	272
err									
M	0.0	0.44	0.0	0.89	1.33	0.0	2.82	0.89	1.11
SD	1.13	0.0	3.61	2.80	2.64	0.0	5.48	2.15	2.74
				Wait group (n = 26)					
Time 1									
RT									
M	677	799	530	712	1076	759	732	1161	918
SD	296	249	238	409	287	198	435	328	246
err									
M	0.72	1.20	1.67	0.95	2.39	1.43	2.63	3.36	0.48
SD	2.04	3.06	3.35	2.32	4.45	2.71	3.60	6.30	0.09
Time 2									
RT									
M	800	793	480	896	1095	706	907	1256	900
SD	454	259	166	594	286	211	625	340	197
err									
M	0.0	0.72	0.0	1.20	1.20	0.72	0.95	1.19	1.67
SD	0.0	0.13	0.0	0.20	2.77	0.15	2.25	2.50	3.0
Time 3									
RT									
M	870	759	446	979	1044	620	1046	1217	857
SD	519	235	205	646	254	209	696	275	236
err									
M	0.48	0.24	0.0	0.24	0.72	0.96	2.40	1.20	0.96
SD	0.09	0.07	0.0	0.06	0.14	3.39	6.66	3.0	2.88

Note. Reaction time values and SOAs are in milliseconds and error rates are percentages.

The tone-detection miss rates on the *yes*-response trials did not exceed 1.0% for any of the exercise groups; the false-alarm rates varied from 1.73% to 2.51% across the three groups.

Cognitive Performance at Times 1 and 2

The analyses of the data for Times 1–3 did not yield any main effect or interaction involving exercise group, for either simple-RT, primary-task RT, or secondary-task RT. Because all of the subjects participated in aerobic exercise training between Times 2 and 3, actual differences among the three exercise groups may not be apparent when all three assessments are included in the analysis. Additional analyses were therefore conducted that included only the older adults' Time-1 and Time-2 data. These analyses were performed on simple-RT, primary-task RT, and secondary-task RT, for both the letter-search and word-comparison tasks. None of these analyses, however, yielded a significant main effect or interaction involving exercise group.

Discussion

Age Differences and Task Differences at Time 1

The analysis of the Time-1 primary-task data demonstrated that an age-related slowing was present in both the letter-search and word-comparison tasks. For the letter-search task, the older adults required more time than the young adults to (a) compare the probe and memory-set letters (as indicated by the age-related increase in the slope values), and (b) identify the probe and select a response (as indicated by the age-related increase in the intercept values). This age-related slowing across all the processing components of short-term memory search is consistent with previous investigations of adult age differences in the Sternberg paradigm (e.g., Anders et al., 1972; Blumenthal & Madden, 1988). Similarly, in the word-comparison task, the age-related increase in the RT difference between the synonym and identical displays replicates the previous findings obtained with this measure of retrieval from long-term memory (Madden, 1985).

The secondary-task data at Time 1 indicated that the attentional demands of both the letter-search and word-comparison tasks were greater for the older adults than for the young adults. For both tasks, the increase in tone-RT on the dual-task trials, relative to the baseline simple-RT trials, was greater for the older subjects than for the young subjects (as reflected in the main effect of age group in secondary-task tone RT). This age-related increase in vulnerability to the attentional demands of the primary task, as measured by secondary-task RT, has occurred previously in several forms of visual classification (Guttentag & Madden, 1987; Madden, 1986) and memory retrieval (Craik & McDowd, 1987).

At Time 1, the letter-search and word-comparison tasks were similar in that the attentional demands increased as a function of the complexity of the primary-task conditions. That is, secondary-task tone-RT increased as a function of memory-set size in letter search and increased with the requirement for semantic retrieval (i.e., synonym RT minus identical RT) in word comparison. In addition, for both tasks, the age difference in the tone-RT measure increased as a function of task complexity (i.e., memory-set size and display type), indicating that the specific processing requirements of both letter search and word comparison were more attention-demanding for the older adults than for the young adults. The changes in secondary-task performance associated with the SOA between the tone and the display, however, illustrated important differences in the attentional demands of the letter-search and word-comparison tasks. At Time 1, the effect of memory-set size in letter-search tone-RT was significant at all three SOAs, whereas the effect of display type on the *yes*-response trials for word comparison was significant only at the 100-ms and 600-ms SOAs (see Figure 2). This difference in the change in tone-RT across SOA represents task-specific attentional demands: In the letter-search task, subjects are holding a memory set in mind and preparing for the probe letter to appear; whereas in the word-comparison task there are no processing demands until the display appears. This different pattern of attentional demands was also evident in the changes in age differences in tone-RT as a function of SOA. For letter search, the age difference in tone-RT was greatest in magnitude at the −400-ms SOA and decreased in magnitude across successive SOAs. For word comparison, in contrast, the age difference in tone-RT was most pronounced (especially for the synonym displays) at the 100-ms SOA.

Effects of Exercise at Times 1–3

The older adults in the present experiment were able to improve significantly their level of aerobic capacity. Over the course of the first 16 weeks, the aerobic group improved their aerobic capacity by 11.02%, whereas the $VO_{2\,max}$ values for the yoga and wait groups remained unchanged. Following the second 16 weeks (the period during which all of the older subjects participated in aerobic exercise training), there was a further increase in aerobic capacity that did not vary significantly as a function of group assignment. The data thus indicate that the observed increases in the $VO_{2\,max}$ values were related to the specifically aerobic properties of the exercise training protocol.

In spite of the older adults' significant improvements in aerobic capacity, there was no exercise-related improvement in any aspect of the cognitive tasks. Several aspects of performance did improve as a function of practice, as reflected in significant main effects for the time variable: The error rates in primary-task performance for both letter search and word comparison, for example, decreased across the three assessments. The RT intercept values in the letter-search data decreased across time, which indicated that subjects became faster, with practice, at identifying the probe letter and selecting a response. Overall primary-task RT for word comparison also decreased across the three assessments. Secondary-task performance, in contrast, was for the most part constant across the three assessments. In this pattern of change and constancy in performance across time, however, there was no main effect or interaction involving exercise group. Limiting the focus of the analysis to Times 1 and 2 also failed to yield any indication of an exercise-related change in RT performance. Thus, although reliable age differences were evident in the present measures of cognitive performance and the older adults improved their level of aerobic capacity significantly, there was no evidence in the present data to suggest that the improvements in aerobic capacity were associated with an improvement in cognitive functioning.

The present results conflict with those of several previous investigations reporting that older adults are able to improve their performance on cognitive tasks as a result of aerobic exercise training (Barry et al., 1966; Dustman et al., 1984; Elsayed et al., 1980). The basis for the difference between the present findings and those of Dustman et al. (1984), in particular, deserves further investigation, because the design of the Dustman et al. protocol closely resembled that of the present study. One potentially important difference between the studies is that the Dustman et al. (1984) subjects improved their aerobic capacity by 27%, whereas in the present experiment, the aerobic group improved their aerobic capacity by 11.02% between Time 1 and Time 2. To demonstrate any exercise-related improvement in cognitive performance, it may consequently be necessary to obtain the substantial improvements in aerobic capacity reported by Dustman et al. (1984). The magnitude of improvement in $VO_{2\ max}$ exhibited by our subjects, however, was equivalent to that reported by Cunningham, Rechnitzer, Howard, and Donner (1987) for older men completing a 1-year program of aerobic exercise training. The present results are also consistent with those of a separate investigation of aerobic exercise training that we have completed (Blumenthal & Madden, 1988), in which healthy men between 30 and 58 years of age improved their aerobic capacity by 15%, over a 12-week period, but did not exhibit any improvement in their performance on a Sternberg memory-search task.

The results of this investigation do not rule out the possibility that improved aerobic capacity, especially as associated with extended periods of exercise training, may be related to the efficiency of central nervous system functioning. Indeed, the effects of long-term exercise training may play a role in the differences in RT performance between relatively active and sedentary groups of older adults (Rikli & Busch, 1986; Spirduso, 1975, 1980; Spirduso & Clifford, 1978). It is also possible, however, that there is a significant genetic component to the RT differences between physically active and sedentary individuals. We find that over the course of approximately 8 months of exercise training, subjects report that they *feel* better, in terms of mood, self-confidence, and different aspects of life satisfaction (Blumenthal et al., in press). But over this time period our subjects do not *perform* better on the types of RT assessments that we have used. We suggest that the exercise-related improvements in cognitive functioning that have been obtained in within-groups designs are dependent on some aspect of either the exercise protocol or the cognitive performance measures that has yet to be determined.

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Received July 20, 1988
Revision received December 8, 1988
Accepted December 9, 1988 ■

Call for Nominations

The Publications and Communications Board has opened nominations for the editorships of *Psychology and Aging,* the *Journal of Experimental Psychology: Animal Behavior Processes, Contemporary Psychology,* the Personality Processes and Individual Differences section of the *Journal of Personality and Social Psychology,* and *Psychological Assessment: A Journal of Consulting and Clinical Psychology* for the years 1992–1997. M. Powell Lawton, Michael Domjan, Ellen Berscheid, Irwin Sarason, and Alan Kazdin, respectively, are the incumbent editors. CAndidates must be members of APA and should be available to start receiving manuscripts in early 1991 to prepare for issues published in 1992. Please note that the P&C Board encourages more participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. To nominate candidates, prepare a statement of one page or less in support of each candidate.

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First review of nominations will begin January 15, 1990.