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Transfer of a Speed of Processing Intervention to Near and Far Cognitive Functions

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Processing, speed · Intervention · Cognitive training

Abstract
Background: Evidence establishing the potential for modification of cognitive functioning in later adulthood has begun to accumulate. ***Objective:*** The primary goal of the current study was to evaluate, among older adults, the extent to which standardized speed of processing training transfers to similar and dissimilar speeded cognitive measures as well as to other domains of cognitive functioning. ***Methods:*** Ninety-seven older adults (mean age 73.71 years) were administered a battery of cognitive tests assessing intelligence, memory, attention, verbal fluency, visual-perceptual ability, speed of processing, and functional abilities. Forty-four of the participants received ten 1-hour sessions of speed of processing training. The remainder of participants were in a no-contact control group. Approximately 6 weeks after the pretraining assessment, all participants repeated the same battery of tests. ***Results:*** The results revealed training effects for some speed of processing measures, including performance of instrumental activities of daily living, but no transfer to other domains of cognitive functioning. ***Conclusion:*** Speed of processing training may enhance the speed at which older adults can perform instrumental activities of daily living.

Introduction

There is a long history of research in cognitive aging that indicates as people grow older, they experience declines in multiple domains of functioning [1]. Cognitive abilities such as speed of information processing, memory, and reasoning ability may be affected, resulting in declines in the ability to perform everyday tasks such as managing money, taking medications, and driving [2–5]. These changes raise a number of questions. First, there is concern that as the percentage of older adults in the general population continues to increase over the next 20–30 years, there will be a growing number of older adults who cannot function independently, thereby placing an emotional and financial strain on the older adults themselves, their caregivers, and society. Second, there is considerable research interest in examining the nature of age-related declines in multiple areas of functioning in order to develop more effective interventions to prevent, slow, or reverse such effects.

Cognitive training studies can be useful in answering questions about potential methods of slowing, preventing, or reversing age-related cognitive decline. Evidence establishing the potential for modification of cognitive functioning in later adulthood has begun to accumulate [6, 7]. This foundation of research provides empirical support for the potential of cognitive interventions to enhance everyday cognition and functional abilities. Cognitive

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training protocols have been developed for the improvement of memory, reasoning, and speed of processing, among other abilities [6, 8–16]. Several training studies have been conducted using the protocol from the Adult Development and Enrichment Project (ADEPT) [5, 6, 11, 17, 18]. The ADEPT training protocol consists of five 60- to 90-min sessions. Two types of training can be administered: figural relations training, which involves teaching strategies to facilitate mental rotation of figures, or reasoning training, which involves teaching different rules or strategies to solve letter series, letter sets, and number series problems. Training studies using the ADEPT protocol have generally found that training results in improvement on several near- and very-near-transfer tasks of the trained ability [7]. However, training effects do not appear to transfer to measures of abilities that were not the focus of training [18]. Specifically, participants who received reasoning training demonstrated significant improvement in tests of reasoning ability, but did not demonstrate improvement on tests of spatial ability. Likewise, participants who received spatial training demonstrated improvement on spatial tests, but not on tests of reasoning ability.

Studies on memory training have involved a variety of training protocols and often have used a multifactorial approach [12, 14, 15]. For example, Oswald et al. [16] compared the effectiveness of five different treatment approaches: competence training, memory training, psychomotor training, combined competence and psychomotor training, and combined memory and psychomotor training. The results indicated that a combined approach of memory and psychomotor training resulted in a reduction of dementia symptoms for up to 2 years following training. Neely and Bäckman [15] conducted a memory training study in which they found transfer of training for recall of concrete words – the task most similar to the training itself. Transfer was also found for another memory task of object recall; however, no transfer was found for subject-performed and abstract words recall tasks.

The present study examines the extent of transfer of speed of processing training. Our protocol for speed of processing training was designed based on the Useful Field of View (UFOV®)[1] concept developed and described by Ball and Owsley [8] and Ball et al. [9, 19]. The UFOV test provides a measure of the visual area from which one can extract information in a single glance without eye or head movements. The UFOV test is a processing speed measure that is expedient for evaluating age-related slowing under a variety of task demands.

Several studies have found that older adults performing poorly on the UFOV test are at greater risk of automobile crashes [3, 20–22]. Furthermore, adults with a reduction in UFOV are more likely to fail an on-the-road driving test [23]. Given such findings, a logical extension of the research is to examine whether speed of processing training results in improved driving performance. Such research has indicated that individuals who received this training demonstrated significantly faster processing on the UFOV test (the nearest transfer measure), showed improved stopping time to road signs while in a driving simulator (a near-transfer measure), and made fewer dangerous maneuvers on an open-road driving test (the functional outcome of interest) [8]. The control group received an equivalent amount of training in a standard driver improvement class, but did not demonstrate these gains. These findings indicated that speed of processing training transfers to near measures of processing speed as well as to the functional outcome of reacting quickly to hazardous situations while driving [8].

The primary goal of the current study was to evaluate the breadth of transfer of speed of processing training to multiple cognitive measures along a conceptually based continuum of near to no transfer (see table 1). A critique of previous training studies has been that only far-transfer tasks have been examined. Therefore, we choose to involve a large range of measures, including both some measures that were closely related to the training and some that were not – a methodology employed by Willis et al. [7]. Various measures commonly used in cognitive aging research across a wide variety of domains such as speed of processing, memory, executive function, visual spatial skills, and crystallized intelligence were included in the protocol.

The UFOV was categorized as the nearest transfer measure because the training protocol is most similar to this assessment test. Furthermore, prior research has found transfer of training to this task [8]. All other measures of speed of processing were categorized as near transfer along the continuum, since processing speed is the construct targeted by training. It was hypothesized that training would most impact UFOV, Road Sign Test, and Timed IADL (instrumental activities of daily living) Test performance, since these rely heavily upon rapid information processing and visual search. The Road Sign Test is similar to the intervention in that it is a speeded task that involves visual search for a target surrounded by distractors. Furthermore, prior research has found transfer of speed of processing training to this measure as per-

[1] UFOV is a registered trademark of Visual Awareness, Inc.

Table 1. Continuum of near and far cognitive measures

Transfer	Type of task	Test
Nearest	Speed of processing	
	Rapid information processing	Useful Field of View
Near	Speed of processing	
	Everyday visual search	Road Sign Test
		Timed IADLs
	Pencil and paper measures	Finding As
		Identical Pictures
		Letter and Pattern Comparison
		WAIS-R Digit-Symbol Substitution
Far	Executive function	Stroop
		Trail-Making Test
		Controlled Oral Word Association
	Memory	Benton Visual Retention
		Rey-Osterrieth Complex Figure Test
		WAIS-R Digit Span
No transfer	Visual-spatial skills	WAIS-R Block Design
		Facial Recognition
	Crystallized intelligence	WAIS-R Information

formed in a driving simulator [8]. The components of the Timed IADL Test also involve visual search in the midst of distracting information, and prior research has indicated that performance on the test is moderately associated with UFOV performance (r = 0.54) [24]. It was further hypothesized that transfer of training would also be evident in the more traditional pencil and paper measures of speed of processing [1] (e.g., Letter and Pattern Comparison, Digit Symbol, Finding As, Identical Pictures).

Measures of executive function and memory were also included in the protocol in order to evaluate breadth of transfer. These measures were categorized as far transfer, because although prior research has indicated that performance on such tasks is associated with speed of processing [25–29], these measures are not considered to be pure markers of the speed construct itself. Furthermore, these measures are not similar to the intervention, and prior research has not found transfer of training to dissimilar tasks [30]. Thus, it was hypothesized that the training would not significantly impact performance on executive function or memory tasks.

Finally, we hypothesized that training would not transfer to performance on visual-spatial or crystallized intelligence measures. These were considered to be no-transfer tasks in that they have not typically been highly associated with speed of processing, and most of the tasks included in the battery – e.g., Wechsler Adult Intelligence Scale (WAIS) Information and Facial Recognition – did not involve a speed component. Although transfer was not expected, these measures were included in the battery in order to truly examine the extent of transfer across a wide variety of cognitive domains.

Methods

Design

The present study was a 2 × 2-mixed design with testing occasions as the within variable and type of training as the between variable. Prior to the start of training, all participants were assessed on a battery of tests of cognitive ability. Following the assessment, participants were randomly assigned to either the training or the control group. Approximately 6 weeks after the pretraining assessment, the participants were again assessed on the cognitive battery. Ninety-one of the participants completed the protocol.

Sample and Procedures

Ninety-seven community-dwelling, older adults (42 males and 55 females; 82 Caucasians, 11 African-Americans, 2 others, 2 unspecified) participated in the study. The sample had an average age of 73.71 (range 61–95) years and an average education of 14.56 (range 6–20) years. The participants were recruited from prior studies and from a university program for older adults called Medwise. This program offers discounts and research opportunities to individuals 55 years and older. All participants resided in Jefferson County, Alabama, or the surrounding area.

Measures

Health Status

Participants were asked whether a doctor or nurse had ever told them that they had any of the following eye conditions: glaucoma, cataract, macular degeneration, retinal detachment, diabetic retinopathy, optic neuritis, or dry eye syndrome. The participants were also asked to self-report whether they had ever had any of the following medical conditions: heart disease, hypertension, arthritis, multiple sclerosis, depression, cancer, stroke, Parkinson's disease, or dizzy spells.

Cognition

Training in speed of processing tasks was expected to improve the participants' speed-related mental functions, but not to generalize to cognitive domains such as crystallized intelligence. In order to demonstrate the presence or absence of training-related improvements in various cognitive abilities, we selected a diverse cognitive battery. Measures were selected for this battery based upon prior evidence indicating that the component tests are relatively pure markers of the cognitive domains of interest: speed of processing, executive function, visual-spatial skills, memory, and crystallized intelligence. Even so, we acknowledge that no test represents a wholly pure measure of a single domain, and virtually all tests tap more than one domain. Thus, in choosing tests for the battery, consideration also was given to the ecological validity of each test, the amount of time and expertise required for test administration, and the availability of age-appropriate normative data for each test. We selected more than one measure of each posited cognitive domain in order to more fully represent each construct of interest. Based upon our empirically based conceptualization of speed of processing and its relationship to other cognitive functions, we constructed a continuum of cognitive domains, with constituent measures of each, ranging from the closest relationship (nearest) to no relationship. These posited relationships underlie our expectation that any speed of processing training benefits would transfer to a greater extent to measures dependent on processing speed (e.g., Useful Field of View, Letter and Pattern Comparison) than to measures independent of processing speed demands – e.g., WAIS-R (revised) Information (see table 1). As noted, the primary outcome variables were represented by multiple markers.

Speed of Processing

Useful Field of View. The UFOV [19] measures the speed at which one can rapidly process multiple stimuli in the visual field. This measure is ecologically valid in that it has been shown to be an excellent predictor of mobility outcomes – and of car crashes in particular – among older adults. In three increasingly complex subtests, central, peripheral, and distractor stimuli are presented as white targets (2 × 1.5 cm) with an otherwise black background on a touch-driven, 17-in computer monitor. The participants view the monitor from a distance of approximately 60 cm. The three subtests require the examinee to identify and localize targets with presentation durations ranging between 17 and 500 ms. Each trial consists of four display screens: (1) a fixation box; (2) a test stimulus; (3) a full-field, white-noise, visual mask, and (4) a response screen. The white-noise visual mask is presented following the stimuli in order to control display speed and to eliminate afterimages.

In the first subtest, basic speed of processing, the examinee identifies a central target (car or truck) presented in a fixation box. In the second subtest, divided attention, the examinee identifies the central target and must also localize a simultaneously presented peripheral target (car). The third subtest, selective attention, also demands simultaneous identification of the central target and localization of the peripheral target. However, in this subtest, the peripheral target is embedded in distractors, making the task more difficult. Peripheral targets are presented 11 cm from the fixation box at one of eight radial locations (0, 45, 90, 135, 180, 225, 270, and 315 degrees). Distractor stimuli are triangles of the same size and luminance as the peripheral target and uniformly fill the spaces between target locations.

For each subtest, the display speed is varied between 17 and 500 ms using a double staircase method in order to determine a threshold of 75%. Three scores are derived indicating the display speed in milliseconds at which examinees could correctly perform each subtest 75% of the time. Scores for each of the three subtests may be combined into a single composite score.

Road Sign Test. The Road Sign Test [8] is a laboratory-based measure of everyday visual search skills. This measure was being developed during the course of this study. The participants view road signs (pedestrian, bicycle, right- and left-turn arrows) with and without a red slash through them on a computer screen. They are instructed to disregard signs with a red slash (distractors) and to respond as quickly as possible, using a computer mouse, to signs without a slash (targets). The participants are instructed to react to right- and left-turn arrows by moving the mouse in the direction indicated by the arrow. They are told to respond to the bicycle and pedestrian signs by clicking a mouse button. The average reaction time in seconds required for a correct response for each trial is recorded.

Midway through the project the Road Sign Test was modified to its present form. Thus, two different versions of the test are included in the present study. In both versions of the test, each condition involves one target stimulus (the sign without a red slash) and a number of distractor stimuli (signs with red slashes). The earlier version of the test includes four different conditions (either 3, 4, 5, or 6 stimuli); this version was completed at both pre- and posttest sessions by 76 participants. For this version, six trials of each condition were completed, for a total of 24 trials.

The revised version of the test also presents a total of 24 trials, but these trials are composed of 12 trials each of the 3- and 6-stimuli conditions (the 4- and 5-stimuli conditions were dropped from the protocol). This revised version of the test was completed at both pre- and posttest sessions by the last 15 participants in the study. The average reaction time was calculated for all participants – those who took the earlier version as well as those who took the modified version – across all trials completed.

Timed IADLs. The Timed IADL Test [24, 31] involves laboratory measurement of five timed tasks that resemble everyday instrumental activities of daily living (finding a telephone number for a given person in the telephone directory; finding and counting out correct change from a group of coins; finding and reading the ingredients on a food can label; finding two food items in an array of food items on a shelf, and finding and reading the directions on a medicine container). Reliability and validity of this instrument, as well as its independent association with processing speed, have been demonstrated within a sample of 173 older adults in the ongoing ACTIVE study, a multisite trial of cognitive interventions [24]. For each of the five IADL tasks, there is a preset time limit of 2 min, with the exception of the telephone task which has a time limit of 3 min. The length of time in seconds required to complete each task is recorded for each participant. If the participant does not complete the task within the preset time limit, testing for the task is terminated. Error codes are assigned for each task reflecting whether the task is (1) completed without error and within the time limit; (2) completed with minor errors, or (3) not completed within the time limit or completed with major errors. For the tasks completed with minor errors, a time penalty is added to the completion time. This added time penalty is equal to 1 SD, based upon the data from the participants who completed the same item without error. The times for each of the tasks are transformed into Z scores which are then summed to form a composite.

Finding As. This test [32] is a timed test of visual scanning and is considered to depend in large part upon processing speed. Participants view 5 pages each with 5 columns of 41 nonsense words and identify the five nonsense words containing an *A* in each column. Participants are given 2 min to complete as many columns as possible. They receive scores that indicate the number of correctly identified nonsense words (i.e., those containing an *A*).

Identical Pictures. The Identical Pictures Test [32] is also considered to be a measure of processing speed. Participants view a target object and are asked to identify the target in a set of five objects to the right of the target. Participants are given 90 s to complete as many items as possible out of 48 target items. The scores reflect the number of correctly identified matches.

Letter and Pattern Comparison. The Letter and Pattern Comparison tasks [33] have been used in numerous studies to tap processing speed [33–35]. The results have consistently indicated a decrease in performance with age. For the Letter Comparison task, participants compare paired sets of letters (containing either 3, 6, or 9 letters per set) and determine whether the sets are the same or different. Thirty-four sets of letters are presented on each page with all sets on a given page consisting of the same set size (3, 6, or 9 letters). Each set size is tested twice for a total of six pages administered. The participants are given 20 s per page to complete as many items as possible. Analogously, for the Pattern Comparison task, the participants compare paired line patterns (containing either 3, 6, or 9 line segments per pattern) and determine whether the patterns are the same or different as quickly as possible. Twelve pages are administered (4 pages for each of the 3, 6, or 9 lines) with 16 pairs per page. Twenty seconds are allowed per page. The numbers of correct determinations for both tasks are totaled and used in subsequent analyses.

WAIS-R Digit-Symbol Substitution Subtest and Digit Symbol Copy. The Digit Symbol task [36, 37] has been described as assessing psychomotor speed and is thought to be relatively unaffected by intelligence, memory, or learning [38]. However, age impacts performance with raw scores dropping considerably over the age of 60 [39]. Age differences on this task persist even when memory and peripheral motor speed are taken into account; these age effects have been attributed to declines in speed of information processing [40].

This test presents a key that pairs digits ranging between 1 and 9 with symbols. Participants view a series of digits and draw below each digit the appropriate symbol. Participants are given 90 s to complete as many substitutions as possible out of a total of 93 items. For each participant the average time in seconds required per correct substitution is determined. In order to control for motor speed, the participants also complete the Digit Symbol Copy measure. This task is analogous to the substitution measure, but requires participants to merely copy the symbols. The time in seconds required to copy all 93 symbols is determined for each participant and converted to the average number of seconds required to copy each symbol. The overall digit-symbol substitution score used in subsequent analysis is the difference between the average number of seconds to substitute each item and the average number of seconds to copy each item. This core is used in order to eliminate the impact of motor speed and obtain a pure measure of perceptual speed.

Executive Function

Stroop Test. A modified version of the Stroop Test [41] was administered using a computer. This task requires the executive functions of inhibition and impulse control [42].

In the first Stroop task (color patches) the participants view two columns of ten colored blocks (red, green, blue, or yellow) on a computer screen and are required to identify the color of each block as quickly as possible. In the second task (color words) the participants are required to read two columns of ten color names printed in black on the computer screen, again as quickly as possible. Finally, for the interference condition, the participants view two columns of ten color names printed in a discordant ink color (e.g., *blue* printed in yellow) and are required to identify, as quickly as possible, the actual color of the ink, while ignoring the color word or name. For each task, the participants receive scores indicating the amount of time in milliseconds required to identify all the stimuli as instructed. In addition, the number of errors made is also recorded for the interference condition. The 'Stroop effect', which quantifies the impact of distraction on the ability to inhibit a primary response, is derived by calculating the difference between the interference condition and the color patch condition times. A correction factor for errors made on the interference task is then added to the Stroop effect score. This correction factor is calculated by dividing the Stroop effect by the number of trials and then multiplying by the number of errors.

Trail-Making Tests (A and B). The Trail-Making Test [43] has been described as a test of complex visual scanning (part A) and mental set flexibility (part B) [42, 44]. As individuals age, the performance on this task tends to slow [38]. The mental set flexibility required for successful performance of part B is an important aspect of executive function. For trails A, the participants draw a line connecting 25 numbered circles in sequence as quickly as possible. For trails B, the participants draw a line connecting 25 circles containing either a number or a letter in alternating sequence as quickly as possible (e.g., 1-A-2-B). The time in seconds required to complete each task is recorded. Participants' scores reflect the difference between the times required to complete trails A and B.

Controlled Oral Word Association Test. This test [45] examines verbal fluency and requires the executive functions of mental flexibility and initiation [38, 42]. Performance on the task relies upon creative and strategic retrieval as well as monitoring of performance and taps executive function [46]. Age differences on verbal fluency tasks have been found, but not consistently [47, 48]. Although there is a time limit involved in the administration of this test, it has not customarily been thought to be a test of speed of processing. However, recent findings suggest that age-related declines on the task may be due to the speed of processing decline [27]. The participants are given 60 s to produce as many words as possible beginning with each of three letters (C, F, and L). The participants receive scores indicating the total number of words produced for all three letters; norms for these scores include correction for gender, age, and education [45].

Memory

Benton Visual Retention Test (BVRT; Form C, Administration A). The BVRT [49] has been described as a test of visual memory. Factor analytic studies have indicated mixed results regarding whether the BVRT loads primarily on a visual-perceptual-motor factor, a psychomotor speed factor, or a memory-attention-concentration factor [50]. The participants are shown a sequence of ten geometric designs, one at a time for 10 s each, and are required to reproduce each design after it has been removed from sight. The scores reflect the number of designs correctly reproduced.

Rey-Osterrieth Complex Figure Test (CFT; Copy and Immediate Recall). The CFT [51] is a test of visual-spatial constructional ability (copy) and visual memory (recall). Most studies report a decline in performance on the CFT recall trials with age which may be attributed to impaired storage of information [50]. The participants view the Rey-Osterrieth complex figure and are asked to copy the figure onto another sheet of paper. Upon completion of this trial, the figure is removed, and the participants immediately reproduce as much of the figure as possible from memory. The participants receive a score for the copy trial and for the memory trial reflecting the number of figure components that were correctly reproduced (based on accuracy of form and placement). Only the memory score was used in subsequent analysis, given that this aspect of the test was of more interest than the constructional component.

WAIS-R Digit Span Subtest (Forward and Backward). The Digit Span [36] is a test of immediate auditory memory span and working memory that relies upon attentional ability [52]. The participants listen to orally presented digit sequences and then repeat them in order (forward). Next, they listen to similar number sequences and repeat these in reverse order (backward). The participants receive scaled scores based on the sum of digit sequence trials repeated correctly (both forward and backward).

Visual-Spatial Skills

WAIS-R Block Design Subtest. This subtest [36] is a measure of visual-spatial organization. Age has a significant impact on the performance of this test primarily in that older adults often take longer to complete the task [38]. The participants use red and white blocks to reproduce designs presented on stimulus cards within a given amount of time. Scaled scores are determined based on correct design arrangements completed within the allotted time.

Facial Recognition Test (Short Form). The Facial Recognition Test [53] examines the ability to recognize faces without a demand on memory [38]. This test mainly taps visual-spatial processing and abstraction ability and is not dependent on processing speed. The participants are shown a front-view photograph of a person and are required to identify the same person in 3 of 6 photographs taken under either similar or different angle or lighting conditions. The scores, which are based on the number of correctly selected matching faces, are corrected for education level.

Crystallized Intelligence

WAIS-R Information Subtest. The information subtest [36] was included as a test of discriminant validity for speed of processing training effects (i.e., any gains in speed of processing should not affect this crystallized ability). This untimed test places no demands on processing speed and has been described as a test of general knowledge that is less affected by aging and cognitive decline [50]. The participants answer a series of questions regarding general factual information. Scaled scores are determined based on the number of correct responses.

Training

Following completion of the pretest battery, the participants were randomly assigned to either a no-contact control group (n = 47) or a speed of processing training group (n = 44). Control participants (39 Caucasians, 4 African-Americans, 2 other, 2 unspecified; 27 females and 20 males) did not receive any training, but participated in both pre- and posttest assessment sessions. This group had a mean age of 73.85 years and an average education level of 14.8 years. The two assessment sessions for the control group were scheduled such that the amount of time that elapsed between the sessions was similar to that of the training participants (approximately 6 weeks apart).

Training participants (38 Caucasians, 6 African-Americans; 26 females and 18 males) were invited to attend ten group training sessions of about 1 h each. These participants had an average age of 73.29 years and an average education level of 14.3 years. All ten of the sessions included 2–3 participants and began with a group discussion of topics such as how attentional skills relate to everyday activities such as driving, avoiding falls, and mobility. Most of the training participants, all but 3, completed at least 8 out of the 10 training sessions. The other 3 participants completed no less than five sessions.

The three subtests that are used to evaluate UFOV are the model for the speed of processing training. The participants do not practice the UFOV test itself, however. Rather, for training purposes, the complexity of the UFOV subtests is modified by holding the duration of the display constant and by gradually increasing the complexity of the central task, the peripheral task, or both. These modifications allow individuals to practice the tasks at customized levels of difficulty until mastery is achieved. Thus, the actual training protocol requires the participant to practice on a variety of stimuli at a variety of stimulus durations. Some of these stimulus configurations may be ones that the individual experienced during UFOV assessment, but the majority of them are not.

Whereas the UFOV test involves varying display durations until an individual's threshold is determined, the training protocol allows display durations to be specified. Particularly, the duration of the display may be specified in multiples of the refresh cycle of the monitor. For a 60-Hz monitor, a single refresh cycle takes approximately 17 ms. This allows individuals to train on a given task at a constant presentation speed, until that task is mastered before progressing to briefer durations.

Each subtest of the UFOV screening test involves the central identification task. In training, however, the center task can be simplified, requiring merely detection of the target, or can be made more difficult, requiring a determination of whether two central targets presented simultaneously are the same or different. Unlike the UFOV test, in which all peripheral targets are presented at a distance of 11 cm from the central target, the training program allows the distance of peripheral targets to be specified at either 2, 6, or 11 cm from the central target. Moving a peripheral target closer to the central target makes the task easier, while moving the target farther toward the periphery of the computer screen makes the task more difficult. The training software allows task complexity to be further modified by changing the color of the peripheral target and/or the luminance of the distractors. The goal of these training techniques is to gradually increase the task difficulty at levels tailored to the individual, in order to present tasks that are challenging, but not too difficult, until mastery of each task is achieved through practice.

Initial training sessions involved an introduction to and practice on the three types of tasks (simple speed of processing, divided attention, and selective attention), with the three different central demands (detection, identification, same/different). In subsequent training sessions, tasks were customized to each participant's ability per the protocol specified below. All sessions included groups of 2–3 participants and began with a group discussion.

A standardized speed of processing training protocol was used in this study. The protocol specifies that for participants with a threshold greater than 30 ms on UFOV subtest 1 individualized speed training begins with a simple speed of processing task. Recall that although individual presentations may be no faster than 17 ms, the threshold represents the average duration at which the participant can perform the task correctly 75% of the time. In this situation, participants practice a central task at progressively faster presentation speeds and at progressively more complex levels (detection, identification, same/different). Practice continues until the participant can perform the identification task correctly 75% of the time at an average duration of 23 ms or less. Once participants reach this criterion, training progresses to the divided attention tasks.

For participants with a threshold equal to or less than 23 ms on UFOV subtest 1, but greater than 50 ms on subtest 2, individualized training begins with the divided attention tasks. The divided attention tasks require the participant to perform a central discrimination task and also to locate a peripheral target (silhouette of a car) that is presented on 1 of 8 radial directions from the center. Our prior experience and research [8] have shown that mastery of this task may be accomplished most expeditiously by using a telescoping method. The basic idea behind this method is first to select a display duration at which the individual has moderate ability to perform the task (i.e., the display duration closest to the baseline threshold average plus 3 ms) and second to bring the peripheral targets closer to the central target (i.e., 2 cm). The participant practices the task under these stimulus conditions until mastery is demonstrated (75% correct performance for two consecutive blocks of practice). The peripheral targets are then moved toward the periphery (i.e., 6 cm), and the practice is repeated until mastery is achieved at the farthest eccentricity (11 cm). This protocol of progressing from near to far peripheral targets with increasingly difficult center tasks and at faster presentation speeds is repeated methodically, until the participant can perform both the central identification task and the peripheral localization task with approximately 75% accuracy, at an average presentation speed of 50 ms or less.

Upon reaching the training criterion for divided attention tasks, training participants progress to training on selective attention tasks. These tasks require the simultaneous performance of a central task (detection, identification, or same/different) and localization of a peripheral target that is embedded in distractors. Training on selective attention tasks begins at a display duration near the individual's threshold, with the peripheral target placed at the nearest eccentricity. As described above, when the participant is able to perform the training task correctly 75% of the time at longer display durations, the task is made more demanding by decreasing display duration and either manipulating the central task difficulty, peripheral target eccentricity, or both. Manipulations of peripheral target color and distractor luminance also are used as means of tailoring the peripheral task to appropriate levels of difficulty for each individual. Practice on the selective attention tasks is continued until a mastery level of 75% correct performance is achieved at an average display duration of 80 ms, or less, with peripheral targets at the most extreme eccentricity, or until ten training sessions have been completed.

Table 2. Frequencies of self-reported eye and medical conditions by group

	Control (n = 47)	Training (n = 44)
Glaucoma	2	7
Cataract	11	11
Macular degeneration	6	4
Retinal detachment	0	1
Diabetic retinopathy	1	2
Optic neuritis	1	0
Dry eye syndrome	4	5
Heart disease	11	11
Hypertension	16	11
Arthritis	18	18
Multiple sclerosis	0	0
Depression	4	5
Cancer	11	6
Stroke	3	2
Parkinson's disease	0	1
Dizzy spells	7	4

Results

The 91 participants who completed both pre- and posttest assessments were included in subsequent analyses. In order to include all of these cases in analyses, substitutions for missing data points were made in the following manner: participants who had completed a measure at pretest, but were missing a posttest score, were assigned their pretest value on the appropriate measure. If both pre- and posttest values were missing for a participant on a particular measure, the overall pretest mean was assigned for both of the missing values. Less than 1% of the data points were missing prior to these substitutions. Considering that (1) all participants completed the same number of trials of the Road Sign Test; (2) there was no change in test version from pre- to posttest for any participants; (3) equivalent proportions of the control group and training group received each version of the test [χ^2 (1, n = 91) = 0.976, p = 0.323], and (4) there were no baseline differences between the training and control groups on the task, we examined performance collapsed across versions rather than assigning missing values for the 15 participants who completed the revised version of the test.

Self-reported frequencies of eye and medical conditions are presented in table 2 by group. Chi-square analyses revealed no significant differences between the training and control groups in the frequency of any of these health conditions (all p values >0.05).

Table 3. Dependent measures before and after testing by group (mean ± SD)

Measure	Control group (n = 47)		Training group (n = 44)	
	before test	after test	before test	after test
Useful Field of View[a]	471.19±266.73	385.38±197.19	507.70±270.51	255.31±159.53
Road Sign Test[a]	1.85±0.47	1.85±0.52	2.03±0.83	1.94±0.79
Timed IADL[a]	-0.07±0.49	0.03±0.58	0.07±0.98	-0.03±0.75
Findings As	23.00±5.75	23.87±7.13	23.98±8.28	23.98±8.89
Identical Pictures	24.68±6.60	26.11±6.42	24.21±6.06	24.82±6.95
Letter/Pattern Comparison	66.11±15.21	67.55±14.46	65.20±18.82	66.50±19.09
Digit Symbol[a]	1.22±0.65	1.19±0.54	1.49±1.21	1.35±0.86
Stroop[a]	21.84±15.17	19.44±18.81	19.14±14.56	18.55±14.54
Trails[a]	69.14±54.01	62.13±50.50	92.30±103.64	86.89±79.52
Controlled Oral Word Association	37.72±11.50	41.40±11.89	39.84±11.75	39.86±11.05
Benton Visual Retention	5.21±2.17	5.72±2.25	4.70±1.99	5.67±2.22
Rey-Osterrieth Complex Figure	11.09±5.38	13.73±6.51	8.75±4.23	11.30±6.00
Digit Span	9.30±2.65	9.38±2.96	9.07±2.43	9.14±2.49
Facial Recognition	43.60±7.01	45.55±4.94	44.25±4.91	44.95±5.77
WAIS-R				
Information	11.62±2.91	12.06±2.86	10.61±2.71	11.14±3.30
Block Design	7.51±2.36	8.00±2.25	7.02±2.56	7.66±2.69

[a] Lower values reflect better performance for these measures.

Multivariate analysis of variance was also conducted in order to determine whether there were differences between the training and control groups at the baseline assessment. Age, years of education, and pretest performance on measures of speed of processing (UFOV, Road Sign Test, Timed IADLs, Finding *A*s, Identical Pictures, Letter/Pattern Comparison, Digit-Symbol Substitution); executive function (Stroop, Trail Making Test, Controlled Oral Word Association); memory (Benton Visual Retention, Rey-Osterrieth Immediate Recall, WAIS-R Digit Span); visual-spatial skills (Facial Recognition and Block Design), and crystallized intelligence (WAIS-R Information) were the dependent variables, and group membership was the independent variable. There was not a significant main effect of group. Thus, no overall significant differences between the two groups at pretest were found: Wilk's $\Lambda = 0.824$, $F(17, 73) < 1$, $p = 0.556$. The mean values and standard deviations for the dependent measures are presented by group in table 3.

Since there was such a wide range of educational levels (6–20 years), and the degree of education is known to impact several of the cognitive domains tapped by the dependent measures [54], education was used as a covariate in subsequent analyses. Multivariate analysis of covariance was conducted in order to compare the two groups' overall performance across testing occasions on the measures of speed of processing, executive function, memory, visual-spatial skills, and crystallized intelligence. Group membership (train vs. control) was the independent variable, and the 16 dependent cognitive measures across two visits were examined. The results revealed that after controlling for education level, there was a significant interaction between cognitive measures, testing occasion, and group: Wilk's $\Lambda = 0.670$, $F(15, 71) = 2.328$, $p = 0.009$. The two groups performed differently across testing occasions and cognitive measures.

In order to further investigate this significant interaction, the multivariate analysis of covariance was followed up with 16 univariate analyses of covariance. In order to hold the influence of education and pretest performance constant, these variables were used as covariates. Group membership was the independent variable, and performance on the measure of interest was the dependent variable.

As expected, after adjustment for education level and pretest UFOV performance, a significant main effect of group was found for posttest performance on the nearest transfer measure: UFOV $F(1, 87) = 37.89$, $p < 0.001$. UFOV performance at pretest was a significant covariate: $F(1, 87) = 100.029$, $p < 0.001$. However, education was not: $F(1, 87) = 2.621$, $p = 0.109$. After controlling for education and pretest UFOV performance, those who com-

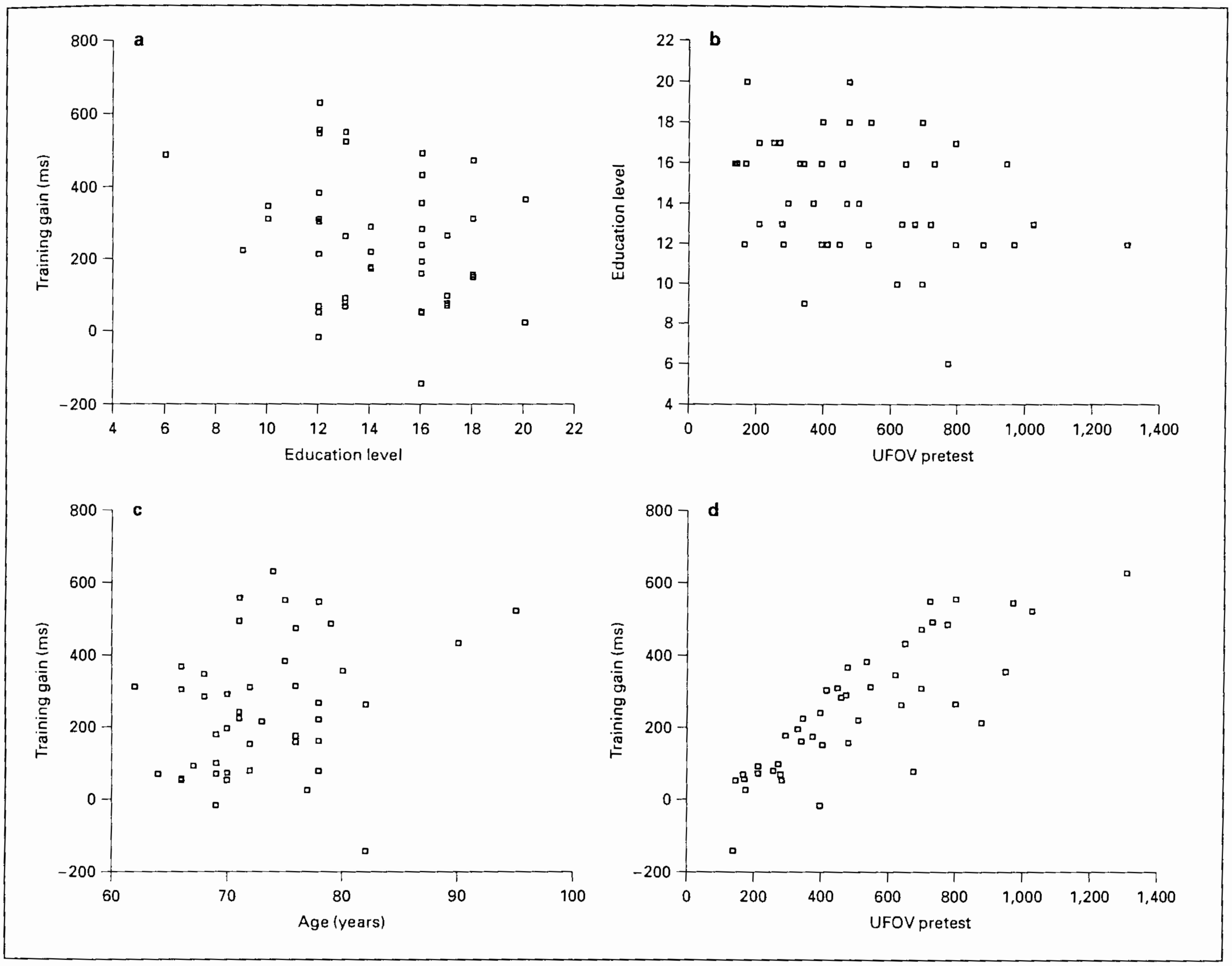

Fig. 1. The relationships among education, age, UFOV and training gains. **a** Education and training gain. **b** Education and UFOV pretest. **c** Age and training gain. **d** UFOV pretest and training gain.

pleted speed of processing training performed significantly better at posttest on the UFOV than did the control group.

A significant main effect of group was also found for Timed IADL posttest performance: $F(1, 87) = 3.984$, $p = 0.049$. Both education and pretest performance were significant covariates for posttest Timed IADL performance: $F(1, 87) = 82.55$, $p < 0.001$ and $F(1, 87) = 9.73$, $p = 0.002$. Overall, after adjusting for education and pretest Timed IADL performance, the trained group performed better on the Timed IADL task at posttest than did the control group.

The training and control groups also performed significantly different at posttest on Controlled Oral Word Association after adjusting for education and pretest performance on the measure: $F(1, 87) = 5.916$, $p = 0.017$. However, for this task, the control group performed better than the training group. While performance at pretest was a significant covariate for posttest performance [$F(1, 87) = 216.79$, $p < 0.001$], education was not [$F(1, 87) = 2.55$, $p = 0.114$]. Whereas the training group experienced essentially no change in the number of words produced for the verbal fluency task from pre- to postassessment, the control group, on average, produced four more words at posttest than at pretest (table 3).

No other significant main effects of group were found for any of the other dependent variables (p values > 0.05). Pretest was a significant predictor of posttest performance for all of the other dependent variables (p values < 0.001). Education was a significant covariate for posttest performance on Digit-Symbol substitution, Identical Pictures, Letter/Pattern Comparison, Stroop, and WAIS information (p values < 0.05). The mean values and standard deviations for all dependent measures are presented in table 3.

The relatively small magnitude of the training effects found in the present study led us to examine select factors that could potentially account for the results. Specifically, we were interested in the relationship between education, initial speed of processing ability, and age, to the amount of gain evident after training. For the speed of processing training participants, we examined the relationships among these variables. Scatterplots illustrating the relationships between baseline UFOV, age, education, and training gains are presented in figure 1. There is a wide range of education in the sample (fig. 1a, b). However, education was not related to training gain (fig. 1a) or baseline UFOV performance (fig. 1b). Similarly, age was not associated with training gain (fig. 1c). The only significant predictor of training gain was initial speed of processing performance (fig. 1d).

Discussion

The primary goal of the present study was to evaluate the extent of transfer of speed of processing training to multiple speed of processing measures, as well as to measures of other domains of cognitive functioning. Initial results revealed a training effect upon the UFOV measure and a transfer of the training effect to Timed IADL performance.

These results, however, were somewhat surprising given that training results obtained in prior studies have been of a greater magnitude and have found transfer to the Road Sign Test [8]. For example, in the most recent study [8], trained participants were 2.5 standard deviations faster following training, relative to the control group, on the composite UFOV score. In the current sample, the effect size for the composite UFOV measure was only 0.62 standard deviations, a significant reduction from the 2.5 observed previously. It is important to note that the sample size of the present study (speed training n = 44) is comparable to the sample size of this previous training study (speed training n = 49).

The methodological differences between the present and prior studies are the most likely explanation for these discrepancies. First of all, the present study employed group training with a fixed number of training sessions as opposed to individual training to criterion as done previously [8]. We wanted to evaluate the feasibility of conducting speed of processing training in groups as opposed to one-to-one, as had been done previously. Through the present study, we discovered that this method of training flowed smoothly and that our trainers were able to work with groups of 2–3 participants at a time. This was of interest because if speed of processing training proves to be an effective intervention for older adults, administering the training to groups would be more practical and economical to implement. Further research will specifically aim at comparing the effectiveness of group versus individualized training methods. Second, whereas previous studies have only included individuals with initial difficulty in speed of processing, as assessed by the UFOV [8], the present study included individuals regardless of their baseline speed of processing skills. We found that individuals who are initially having difficulty with speed of processing, as assessed by UFOV, are more likely to benefit from training (see fig. 1). However, it is important to consider that the present study only examined the short-term impact of training. It may be the case that individuals who do not have baseline speed of processing difficulties show long-term benefits rather than significant short-term changes. Ongoing research is aimed toward investigating this possibility.

As previously mentioned, the present study included a more diverse sample of older adults than have prior studies. Inclusion criteria were minimal in order to investigate the impact of the training in a more representative sample of the general 65 years and older population. A weakness of the present study is that no comprehensive screening assessment for dementia was included. It is possible that some of the participants could have suffered from pathology that may have interfered with their ability to improve with training. For example, Baltes et al. [55] found that older persons who were at risk of Alzheimer's disease showed no gains with cognitive training, whereas all normal participants did improve with training. Similarly, the present study sample could have included a few individuals at risk of dementia or who had suffered from recent stroke, and inclusion of such individuals could have also contributed to the lack of transfer. Unfortunately, these issues cannot be addressed by the current study. Overall, further research should aim to identify who potentially may (e.g., individuals with speed of processing deficits) and may not (e.g., individuals with or at risk for dementia) benefit from training.

In summary, the results of this study are consistent with results of previous research, indicating that speed of processing training led to improvements in UFOV performance. Also, the results are consistent with previous speed of processing, memory, and reasoning training studies, in which training effects did not transfer to measures in other domains of cognitive functioning [8, 15, 18].

Even though there was an overall lack of transfer of training to cognitive measures, the significant impact of training upon Timed IADL performance is promising. This finding is consistent with the notion that, in general, everyday performance is more strongly related to fluid abilities than to crystallized intelligence [56]. Specifically, the fluid abilities of memory span [57] and speed of processing [31, 57] have been shown to affect older adults' performance of IADLs. Thus, interventions that improve or maintain fluid abilities might be expected to enhance or extend older adults' independent daily functioning. Furthermore, it is encouraging that these significant training effects were found with a general sample of community-dwelling older adults rather than a restricted sample selected to optimally benefit from training.

These results indicate that there is potential for speed of processing training to enhance the everyday functioning of older adults. Determining the most effective methods of administering the training and identifying the specific populations who will most benefit from this training are goals for further investigation.

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References

1 Schaie KW: Intellectual Development in Adulthood: The Seattle Longitudinal Study. New York, Cambridge University Press, 1996.

2 Kausler DH: Learning and Memory in Normal Aging. New York, Springer, 1994.

3 Owsley C, Ball K, McGwin GJ, Sloane ME, Roenker DL, White MF, Overley ET: Visual processing impairment and crash risk among older adults. JAMA 1998;279:1083–1088.

4 Salthouse TA: Influence of processing speed on adult age differences in learning. Swiss J Psychol 1995;54:102–112.

5 Willis SL, Jay GM, Diehl M, Marsiske M: Longitudinal change and prediction of everyday task competence in the elderly. Res Aging 1992;14:68–91.

6 Hayslip B, Maloy RM, Kohl R: Long-term efficacy of fluid ability interventions with older adults. J Gerontol B Psychol Sci Soc Sci 1995; 50:P141–P149.

7 Willis SL, Bliezner R, Baltes PB: Intellectual training research in aging: Modification of performance on the fluid ability of figural relations. J Educ Psychol 1981;73:41–50.

8 Ball K, Owsley C: Increasing mobility and reducing accidents of older drivers; in Schaie KW, Pietrucha M (eds): Mobility and Transportation in the Elderly. New York, Springer, 2000, pp 213–251.

9 Ball KK, Beard BL, Roenker DL, Miller RL, Griggs DS: Age and visual search: Expanding the useful field of view. J Opt Soc Am A Opt Image Sci Vis 1988;5:2210–2219.

10 Baltes MM, Kuhl K, Gutzmann H, Sowarka D: Potential of cognitive plasticity as a diagnostic instrument: A cross-validation and extension. Psychol Aging 1995;10:167–172.

11 Baltes PB, Willis SL: Plasticity and enhancement of intellectual functioning in old age: Penn State's Adult Development and Enrichment Project (ADEPT); in Craik FIM, Trehub S (eds): Aging and Cognitive Processes. New York, Plenum Press, 1982, pp 353–390.

12 Caprio-Prevette MD, Fry PS: Memory enhancement program for community-based older adults: Development and evaluation. Exp Aging Res 1996;22:281–303.

13 Kramer A, Larish JF, Strayer DL: Training for attentional control in dual task settings: A comparison of young and old adults. J Exp Psychol Appl 1995;1:50–76.

14 Mohs RC, Ashman TA, Jantzen K, Albert M, Brandt J, Gordon B, Rasmusson X, Grossman M, Jacobs D, Stern Y: A study of the efficacy of a comprehensive enhancement program in healthy elderly persons. Psychiatry Res 1998; 77:183–195.

15 Neely AS, Bäckman L: Effects of multifactorial memory training in old age: Generalizability across tasks and individuals. J Gerontol B Psychol Sci Soc Sci 1995;50:P134–P140.

16 Oswald WD, Rupprecht R, Gunzelmann T, Tritt K: The SIMA-Project: Effects of one year cognitive and psychomotor training on cognitive abilities of the elderly. Behav Brain Res 1996;78:67–72.

17 Schaie KW, Willis SL: Can decline in intellectual functioning be reversed? Dev Psychol 1986;22:223–232.

18 Willis SL, Schaie KW: Cognitive training in the normal elderly; in Forette F, Christen Y, Boller F (eds): Plasticité cérébrale et stimulation cognitive. Paris, Fondation Nationale de Gérontologie, 1994.

19 Ball KK, Roenker DL, Bruni JR: Developmental changes in attention and visual search throughout adulthood. Adv Psychol 1990;69: 489–508.

20 Ball K, Owsley C, Sloane M, Roenker D, Bruni J: Visual attention problems as a predictor of vehicle crashes in older drivers. Invest Ophthalmol Vis Sci 1993;34:3110–3123.

21 Owsley C, McGwin G, Ball K: Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. Opthalmic Epidemiol 1998;5:101–113.

22 Owsley C, Ball K, Sloane M, Roenker D, Bruni J: Visual/cognitive correlates of vehicle accidents in older drivers. Psychol Aging 1991;6: 403–415.

23 Myers RS, Ball KK, Kalina TD, Roth DL, Goode KT: Relation of useful field of view and other screening tests to on-road driving performance. Percept Mot Skills 2000;91:279–290.

24 Owsley C, Sloane M, McGwin G, Ball K: Timed Instrumental Activities of Daily Living (TIADL) Tasks: Relationship to cognitive function and everyday performance assessments in older adults. Gerontology, in press.

25 Bashore TR, Ridderinkhof KR, van der Molen WW: The decline of cognitive processing speed in old age. Curr Dir Psychol Sci 1998;6:163–169.

26 Bryan J, Luszcz MA: Speed of information processing as a mediator between age and free-recall performance. Psychol Aging 1996;11: 3–9.

27 Bryan J, Luszcz MA, Crawford JR: Verbal knowledge and speed of information processing as mediators of age differences in verbal fluency performance among older adults. Psychol Aging 1997;12:473–478.
28 Lindenberger U, Mayr U, Kliegl R: Speed and intelligence in old age. Psychol Aging 1993;8: 207–220.
29 Salthouse TA: The aging of working memory. Neuropsychology 1994;8:535–543.
30 Bliezner R, Willis SL, Baltes PB: Training research in aging on the fluid ability of inductive reasoning. J Appl Dev Psychol 1981;2:247–265.
31 Owsley C, McGwin G, Sloane M, Stalvey B, Wells J: Timed instrumental activities of daily living (TIADL) tasks: Relationship to visual function in older adults. Optom Vis Sci 2001; 78:350–359.
32 Ekstrom RB, French JW, Harman H, Derman D: Kit of Factor Referenced Cognitive Tests. Princeton, Educational Testing Service, 1976.
33 Salthouse TA: Mediation of adult age differences in cognition by reductions in working memory and speed of processing. Psychol Sci 1991;2:179–183.
34 Salthouse TA, Hambrick DZ, McGuthry KE: Shared age-related influences on cognitive and noncognitive variables. Psychol Aging 1998; 13:486–500.
35 Salthouse TA, Meinz EJ: Aging, inhibition, working memory, and speed. J Gerontol B Psychol Sci Soc Sci 1995;50:P297–P306.
36 Wechsler D: WAIS-R Manual. New York, The Psychological Corporation, 1981.
37 Tun PA, Wingfield A, Lindfield KC: Motor-speed baseline for the Digit-Symbol Substitution Test. Clin Gerontol 1997;18:47–51.
38 Lezak MD: Neuropsychological Assessment, ed 3. New York, Oxford University Press, 1995.
39 Ivnik RJ, Malec JF, Smith GE, Tangalos EG et al.: Mayo's older Americans normative studies: WAIS-R norms for ages 56–97. Clin Neuropsychol 1992;6:1–30.
40 Salthouse TA: What do adult age differences in the Digit Symbol Substitution Test reflect? J Gerontol 1992;47:P121–P128.
41 Trenerry MR, Crosson B, DeBoe J, Leber WR: Stroop Neurological Screening Test. Florida, Psychological Assessment Resources, 1989.
42 Stern RA, Prohaska ML: Neuropsychological evaluation of executive functioning. Am Psychiatr Press Rev Psychiatry 1996;15:243–266.
43 Spreen O, Strauss E: A Compendium of Neuropsychological Tests. New York, Oxford University Press, 1991.
44 Reitan RM: Trail Making Test: Manual for Administration, Scoring and Interpretation. Indianapolis, Department of Neurology, Indiana University Medical Center, 1958.
45 Benton AL, Hamsher K: Multilingual Aphasia Examination. Iowa City, AJA Associates, 1983.
46 Parker DM, Crawford JR: Assessment of frontal lobe function; in Crawford JR, Parker DM, McKinlay WW (eds): A Handbook of Neuropsychological Assessment. Hillsdale, Erlbaum, 1992, pp 267–291.
47 Salthouse TA: Speed and knowledge as determinants of adult age differences in verbal tasks. J Gerontol B Psychol Sci Soc Sci 1993;48:P29–P36.
48 Schaie KW: The Seattle Longitudinal Study: A 21-year exploration of psychometric intelligence in adulthood; in Schaie KW (ed): Longitudinal Studies of Adult Psychological Development. New York, Guilford Press, 1983, pp 64–135.
49 Sivan AB: Benton Visual Retention Test, ed 5. San Antonio, The Psychological Corporation, 1992.
50 Spreen O, Strauss E: A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary, ed 2. New York, Oxford University Press, 1998.
51 Meyers JE, Meyers KR: Rey Complex Figure Test and Recognition Trial: Professional Manual. Odessa, Psychological Assessment Resources, 1995.
52 Heilman KM, Valenstein E: Clinical Neuropsychology, ed 3. New York, Oxford University Press, 1993.
53 Benton AL, Sivan AB, Hamsher K, Varney NR, Spreen O: Contributions to Neuropsychological Assessment: A Clinical Manual, ed 2. New York, Oxford University Press, 1994.
54 Collie A, Shafiq-Antonacci R, Maruff P, Tyler P, Currie J: Norms and the effects of demographic variables on a neuropsychological battery for use in healthy ageing in Australian populations. Aust NZ J Psychiatry 1999;33:568–578.
55 Baltes MM, Kuhl K, Sowarka D: Testing for limits of cognitive reserve capacity: A promising strategy for early diagnosis of dementia? J Gerontol 1992;47:P165–P167.
56 Diehl M, Willis SL, Schaie KW: Everyday problem solving in older adults: Observational assessment and cognitive correlates. Psychol Aging 1995;10:478–490.
57 Willis SL: Cognition and everyday competence; in Schaie KW, Lawton MP (eds): Annual Review of Gerontology and Geriatrics. New York, Springer, 1991, vol 11.