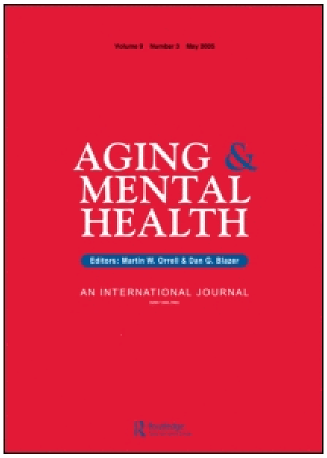

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ORIGINAL ARTICLE

The impact of speed of processing training on cognitive and everyday performance

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Abstract

The purpose of the present investigation was to examine the impact of speed of processing training on the cognitive and everyday abilities of older adults with initial processing speed or processing difficulty. Participants were randomized to either a speed of processing intervention or a social- and computer-contact control group. Results indicate that speed of processing training not only improves processing speed, as indicated by performance on the Useful Field of View test (UFOV®), but also transfers to certain everyday functions, as indicated by improved performance on Timed Instrumental Activities of Daily Living (Timed IADL). Transfer of speed of processing training to other cognitive domains was not evident. This study provides additional evidence that speed of processing training has the potential to enhance everyday functions that maintain independence and quality of life, particularly when the training is targeted toward individuals who most need it. Further study is needed to learn about the long-term effects of such training in relation to everyday abilities.

Introduction

With increasing age, cognitive abilities can decline, resulting in difficulties with performance of everyday tasks such as driving, taking medications, and managing money (Kausler, 1994; Owsley et al., 1998; Salthouse, 1995; Schaie, 1996; Willis, Jay, Diehl & Marsiske, 1992). Considering current population trends toward longevity, there is increasing concern that a significant number of older adults will not be able to function independently, thereby placing emotional and financial strain on themselves, their family members, and society as a whole. Therefore, the investigation of interventions designed to enhance cognition is of importance. It is hoped that such interventions can prevent, slow, or reverse age-related cognitive decline, thereby prolonging functional independence.

Past research has established that cognitive abilities can be improved in older adulthood with specific protocols developed for the improvement of memory, reasoning, and speed of processing, among other abilities (i.e., Ball, Beard, Roenker, Miller & Griggs, 1988; Baltes & Willis, 1982; Caprio-Prevette & Fry, 1996; Hayslip, Maloy & Kohl, 1995; Mohs et al., 1998; Neely & Bäckman, 1995; Oswald, Rupprecht, Gunzelmann & Tritt, 1996). Although less prevalent in the literature than memory and reasoning training studies, training programs for older adults that seek to improve information processing speed are especially promising for their potential to impact older adults' functional abilities. This training approach arises from the theory that changes in cognitive function with age result from generalized, age-related slowing of processing speed (Birren, Woods & Williams, 1980; Salthouse, 1996). In the cognitive training literature, various approaches targeting speed of processing have included extended practice or strategy training on paper and pencil measures of processing speed, computerized training protocols, and training that focuses on attention and dual task processing, which are highly dependent on processing speed. For example, Beres and Baron examined the effects of extended practice on speed of processing performance on a paper and pencil measure, the Digit Symbol Substitution Test (Beres & Baron, 1981). Both young and older adults improved in speed of processing performance with practice. A study from the Adult Development and Enrichment Project (ADEPT; Baltes & Willis, 1982)

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demonstrated a close relationship between attention and perceptual speed performance (Willis, Cornelius, Blow & Baltes, 1983). Older adults who received attentional training were compared to social- and no-contact control groups. Training was found to significantly improve performance on three measures of attention.

Also closely related to speed training is training for dual task performance. Essentially, dual task performance requires rapid information processing and divided attention skills, as well as attention switching and meta-cognitive abilities such as self-monitoring and cognitive resource management. In a study by Kramer and colleagues, young and old adults were strategy-trained on simultaneous performance of two tasks, monitoring and reacting to a series of gauges presented on a computer monitor while also performing an alphabet-arithmetic task (Kramer, Larish & Strayer, 1995). Half of the participants were trained using a fixed priority technique (feedback indicated that both tasks were always equally important) and the other half of the participants were trained using a variable priority technique (feedback alternately emphasized the importance of one task, the other, or both in order to encourage mastery of each individual component of the task separately while still retaining the practice of simultaneous performance of both). Variable priority training improved performance of both young and older adults. Overall, research from these studies and with many different types of cognitive interventions has indicated that older adults improve on tasks similar to those practiced in training, but transfer of cognitive training to dissimilar tasks has been limited (Kramer & Willis, 2002; Neely & Bäckman, 1995; Willis, Blieszner & Baltes, 1981; Willis & Schaie, 1994).

The present study involved a computerized speed of processing training protocol developed by Ball and colleagues (Ball, Beard, Roenker, Miller & Ball et al., 1988). Results of previous studies utilizing this protocol have been mixed with respect to the magnitude and generalizability of training gains. A large-scale, randomized, clinical trial, ACTIVE, recently evaluated the impact of three promising cognitive interventions upon everyday performance (Ball et al., 2002), including the computerized speed of processing intervention used in the present study. Like prior studies of cognitive interventions, results to date from the ACTIVE study have only indicated improvement on tasks very similar to the training exercises practiced. Although the ACTIVE study did not find wide transfer of the speed of processing training intervention, other recent research has indicated that speed of processing training transfers to improved everyday abilities, including Timed Instrumental Activities of Daily Living (Timed IADL; Edwards et al., 2002) and on-the-road driving performance (Roenker, Cissell, Ball, Wadley & Edwards, 2003). Both of these tasks reflect everyday abilities and bear no resemblance to the tasks practiced in the speed of processing intervention. Although both of these studies found transfer of speed of processing training to everyday performance, interestingly, the study by Edwards and colleagues found a relatively small magnitude of the training effect on processing speed measures. Unlike the Roenker and colleagues study (2003), the Edwards et al. (2002) and ACTIVE studies did not administer the intervention only to individuals with initial speed of processing difficulty and used group (two to three participants and one trainer) rather than individual (one participant and one trainer) training formats. Thus, there are at least two possible reasons for the difference in outcomes between the Roenker et al. (2003) study and the Edwards et al. (2002) study. It could be that more interaction and guidance received from a trainer in a one-to-one format (e.g., in the study by Roenker et al., 2003) results in greater training gains than when training is conducted in a group format (e.g., Edwards et al. [2002] and ACTIVE); and/or it could be the case that those with baseline processing speed difficulty (e.g., Roenker et al., 2003) are more likely to show transfer to improved performance on tasks not specifically targeted by the intervention than when training is administered to individuals with minimal impairment in processing speed (e.g., Edwards et al. [2002] and ACTIVE). These methodological differences may be responsible for both diminished training effects and limited transfer.

The purpose of the present investigation was to further examine the impact of speed of processing training by controlling for these methodological differences, and thus elucidate differing results among previous studies. The impact of speed of processing training upon the cognitive and everyday abilities of older adults was examined in a more targeted sample than that used in the ACTIVE (Ball et al., 2002) or Edwards et al. (2002) studies. Furthermore, individual and group training methods were compared. At the same time, this study held constant key variables that otherwise might cloud the results by including a control group that experienced the same amount of social contact and computer exposure as did the experimental group.

In the present study, only individuals who evidenced speed of processing difficulties were randomized to either speed of processing training or the control group. Individuals were required to demonstrate adequate vision and hearing as well as intact mental status to participate. Although it is obvious that individuals who initially perform poorly on speed of processing would be more likely to show improvement on speed of processing tasks following training, we proposed that such individuals would also be more likely to experience transfer of training to improved everyday performance. Thus, we hypothesized that transfer of speed of processing training to tasks beyond the Useful Field of View test

(UFOV®, the test most like the training exercises) would be evident in a sample of older adults who at baseline demonstrated slow speed of processing. Although group versus individual training methods might explain diminished or limited transfer results in the Edwards et al. (2002) and ACTIVE studies (Ball et al., 2002), we proposed that participants would benefit equivalently from the speed of processing intervention regardless of format. Thus, we hypothesized that method of speed of processing training (group versus individual) would not significantly impact the magnitude of training gain such that those who received individual speed of processing training would perform equivalently post-training as those who received group speed of processing training.

Method

Participants

Community-dwelling adults were recruited from a variety of sources and tested at either Western Kentucky University (WKU) or the University of Alabama at Birmingham (UAB). Participants at both sites were recruited from advertisements in community newspapers and through community organizations. Additionally, older adults residing in Alabama received letters inviting them to participate, and participants of past and present research studies at both sites were asked to refer friends and relatives to participate.

All participants in the present study are a part of a larger, ongoing study, 'SKILL—Staying Keen in Later Life.' At the point of data extraction for this report, 613 adults between the ages of 62 and 94 (M = 73.80) had been screened for participation. The overall SKILL sample included 41% men, 59% women, 10% African-Americans, and 90% Caucasian-Americans, and had an average education level of 'some college or vocational training after high school'. Seventy (11%) of the individuals who completed screening refused further participation, primarily due to the time demands of the study.

Of those who agreed to participate in the study, 181 (33%) were eligible for training based on the following criteria: grossly intact mental status (MMSE 23 or better), adequate vision (far visual acuity 20/80 or better, contrast sensitivity 1.35 or better) and hearing (pure tone average of 40dB or better), and a speed of processing deficit (UFOV® subtest 3 and 4 combined score $\geq$800 or subtest 2 score $\geq$150) that allowed room for improvement with training.

All cut-points for inclusion were based upon prior research. The MMSE criterion was chosen to represent grossly intact mental function (Folstein, Folstein & McHugh, 1975) and was based on prior findings that older persons at risk for dementia do not improve with cognitive training (Baltes, Kuhl & Sowarka, 1992). Both the visual acuity and contrast sensitivity criteria were chosen based on past research to insure adequate visual ability to view measures and training stimuli (Owsley, Ball & Keeton, 1995). The hearing criteria were chosen to insure adequate ability to discern human speech in order to understand instructions for testing measures and to participate in training (Katz, 1985). The speed of processing criteria are based on several studies indicating that older adults performing poorly on the UFOV® test (as defined in this study) are at greater risk for adverse functional outcomes (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Myers, Ball, Kalina, Roth & Goode et al., 2000; Owsley et al., 1998; Owsley, Ball, Sloane, Roenker & Bruni, 1991).

One hundred and twenty-six participants had completed the study at the time of data extraction. This sub-sample was, on average, 76 years of age (63–87) and was composed of 16% African-Americans and 37% men. Like the overall sample, these participants had an average education level of 13 years, indicating 'some college or vocational training after high school'.

Procedure

Participants completed a 1½-hour screening visit to determine eligibility for the study and a baseline assessment (2½-hour visit) of speed of processing, memory, executive function, everyday abilities, and a questionnaire on computer experience (detailed below).

Training-eligible participants were randomly assigned to either a speed of processing intervention ($n = 63$) or a social and computer-contact control group ($n = 63$) who underwent Internet training. Internet training was chosen instead of a no-contact condition to control for both social contact and computer exposure. Most participants completed training in group format (two to three participants and a trainer; $n = 94$ [46 speed; 48 Internet]), but in order to compare different training formats, one fourth of the participants were randomly assigned to the individual training format (one participant and a trainer; $n = 32$ [17 speed, 15 Internet]). Across conditions 10 training sessions were led by a trainer and were one hour in duration, during which participants took part in a brief discussion and subsequently practiced exercises on a computer (as described in more detail below). Immediately following training, participants repeated the same set of measures of speed of processing, memory, executive function, and everyday abilities as during baseline.

Screening measures

- *Sensory*

Far visual acuity. Visual acuity was tested with the participant's available correction, if any. Scores were assigned using both the ACTIVE method (Ball et al., 2002; Jobe et al., 2001), which provides credit for each letter correctly identified and ranges between 0 and 90, and the traditional Snellen method. (The Snellen method is the standard scoring method used in ophthalmology and optometry and involves a fraction score in which the numerator represents the distance at which the test was administered and the denominator represents the distance at which the letter stimulus was designed). The ACTIVE scores were used in analyses. Participants were required to demonstrate Snellen acuity of 20/80 or better for inclusion. Three individuals did not meet these criteria.

Pelli-Robson Contrast Sensitivity. Vision was also assessed with the Pelli-Robson Contrast Sensitivity chart. Participants were required to score 1.35 $\log_{10}$ or better for inclusion. Six individuals did not meet these criteria.

Hearing. Pure-tone hearing thresholds were tested via the GSI-17 Audiometer using standard threshold procedures at 500, 1000, and 2000 Hz in each ear. A pure-tone threshold of 40 dB or better was required for inclusion in training. If individuals could not demonstrate a pure-tone threshold of 40 dB or better, but did have hearing aids, they were re-tested with their aids at 40 dB for each frequency in the better ear. If such individuals could hear the three tones at 40 dB with their aids, they were allowed to participate. Fourteen individuals were excluded. The average of all thresholds was used in subsequent data analyses.

- *Mental status*

MMSE (Folstein et al., 1975). The Mini-Mental Status Exam was used to briefly assess mental status and diminish the possibility of including participants with dementia. Scores of 23 or better out of a maximum 30 were required for inclusion in training. Nineteen of the participants who were screened did not meet this criterion.

Experimental measures

- *Computer experience*

Computer Experience Questionnaire (Czaja & Sharit, 1998). Given that many of the testing measures and the training itself involved use of computers, we included a Computer Experience Questionnaire to be used as a possible covariate.

- *Speed of processing*

UFOV® (Ball & Owsley, 1993; Ball et al., 1993). The UFOV® measures the speed at which one can rapidly process multiple stimuli across the visual field. This measure is especially useful in that it is a good predictor of everyday performance and mobility outcomes among older adults. The touch PC version of the test was administered with four subtests, which evaluate speed of processing under increasing cognitive demand and require the examinee to identify and localize targets with presentation durations ranging between 17 and 500 ms. For each subtest, presentation speeds are varied by a double-staircase method in order to derive the 75% threshold. These four scores are combined into a single composite score. In the first subtest, participants identify a central target (car or truck) presented in a fixation box. In the second subtest, the central target must be identified and a peripheral target, which is simultaneously presented (car), must be localized. The third and fourth subtests also demand simultaneous localization of the peripheral target. However, in these conditions, the peripheral target is embedded in distractors, making the task more difficult. While the central task is the same (identification of a single target) in subtest three, the central task of the fourth subtest is more difficult, requiring the determination of whether two objects presented inside the fixation box are the same (car, car; truck, truck) or different (car, truck).

Road Sign Test. The Road Sign Test (RST; Ball et al., 2002; Ball & Owsley, 2000; Edwards et al., 2002) is a computerized measure of everyday speed adapted from the version administered via driving simulator (Roenker et al., 2003). On a computer screen, participants view road signs (pedestrian, bicycle, right and left turn arrows) with and without a red slash. 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). Required reactions are moving the mouse to the left (in response to a left turn sign) or right (in response to a right turn sign), and clicking a button on the mouse (in response to a bicycle sign or pedestrian sign). Prior to the test trials, all participants practiced clicking and moving the mouse until proficiency was demonstrated. The RST includes two conditions in which either three or six signs are displayed at a time, and each condition includes 12 trials. The average reaction time is calculated across all trials completed.

Timed IADL (Owsley, McGwin, Sloane, Stalvey & Wells, 2001; Owsley, Sloane, McGwin & Ball, 2002). The Timed IADL test involves laboratory measurement of five timed tasks that simulate everyday instrumental activities of daily living. Like the RST, this test has been classified as an everyday speed measure (Ball et al., 2002). Tasks include: 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 specified food items in an array of food items on a shelf; and finding and reading the directions on a medicine container. For each of the five IADL tasks, there is a pre-set time limit of two minutes, with the exception of the telephone task, which has a time limit of three minutes. Time in seconds required to complete each task is recorded. If the participant does not complete the task within the pre-set time limit, testing for that particular 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 completion time. This added time penalty is equal to one standard deviation, 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 equally weighted to form a composite.

Letter and Pattern Comparison (Salthouse, 1991). The Letter and Pattern Comparison tasks have been used in numerous studies to tap processing speed (Salthouse, 1991; Salthouse, Hambrick & McGuthry, 1998; Salthouse & Meinz, 1995). Results have consistently indicated a decrease in performance with age. For the Letter Comparison task, participants compare paired sets of letters (containing either three, six, or nine letters per set) and determine whether the sets are the same or different. Participants are given 20 seconds per page to complete as many items as possible. Analogously, for the Pattern Comparison task, participants compare paired line patterns (containing either three, six, or nine line segments per pattern) and determine whether the patterns are the same or different as quickly as possible. Twenty seconds are allowed per page. The number of correct determinations for both tasks are totaled.

WAIS-R Digit-Symbol Substitution (Wechsler, 1981) and Digit Symbol Copy (Tun, Wingfield & Lindfield, 1997). The Digit Symbol task has been described as assessing psychomotor speed (Lezak, 1995). Age differences on this task have been attributed to declines in speed of information processing (Salthouse, 1992). 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 seconds 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, participants also complete a 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 score is used in order to eliminate the impact of motor speed and obtain a pure measure of perceptual speed.

- *Executive function*

Stroop. A modified, computerized-version of the Stroop test (Trenerry, Crosson, DeBoe & Leber, 1989) was administered. This test involves three tasks and requires the executive functions of impulse control and inhibition (Stern & Prohaska, 1996). For each task, participants are asked to perform as quickly as possible, without making errors, but if they do make errors to correct them and proceed. In the first Stroop task (color patches), participants view 36 (presented in four columns of nine) colored blocks (red, green, blue, or yellow) on a computer screen and are required to identify the color of each block. In the second task (color words), participants are required to read 36 color names printed in white on the computer screen. Finally, for the interference condition, participants view 36 color names printed in a discordant ink color (e.g., yellow printed in red). Identification of the actual color of the ink is required while ignoring the color word. For each task, participants receive scores indicating time in seconds required to identify all the stimuli as instructed. The number of uncorrected errors is also recorded for the interference condition. The ‘stroop effect’ (an indicator of the impact of distraction on the ability to inhibit a primary response) is derived by calculating the difference between the interference and color patch condition times. A correction factor, calculated by dividing the interference condition total time by 36 (to estimate time per item) and multiplying by the number of uncorrected errors made, is added to the score.

Trail Making Test (A and B). The Trail Making Test (Spreen & Strauss, 1991) is a commonly used measure that has been described as a test of complex visual scanning (Part A) and mental set flexibility (Part B) (Reitan, 1958; Stern & Prohaska, 1996). In Trails A, participants are instructed to draw a line connecting 25 numbered circles in proper order as quickly as possible. For the Trails B task, 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.

- *Memory*

WMS-III Digit and Spatial Span subtests. The Wechsler Memory Scale III (WMS-III) Digit Span and Spatial Span subtests were administered to assess verbal and non-verbal STM. For the Spatial Span task, participants viewed a white board that contained 10 blue pegs. The tester touched a number of pegs (between 2 and 9) in a specified order for one second each, and the participant repeated the tester's actions. For the Digit Span task, the tester read aloud a series of digits (between 2 and 9), and the participant repeated the series aloud. For both tests, blocks of two trials of an increasing number of items were presented until the participant missed both items within a block, and one point for each correct response was given. The raw score of total number of trials correct was used for each subtest.

Training. Both conditions involved 10 one-hour training sessions that began with a 10–15 minute discussion of topics relevant to the training conditions and ended with 45–50 minutes of individual practice exercises guided by a trainer. Both conditions involved practice exercises with a computer and were completed over the course of five weeks. Participants who attended at least 80% of the sessions (8/10) were considered to have completed the training protocol. The intervention and control conditions were identical with the exception of topics of discussion and type of exercises practiced on the computer.

Through discussion led by the trainer, participants in the Internet training condition received introductions to computer hardware, as well as how to use the mouse, how to acquire and use an E-mail account, and how to access and use web-pages. Participants individually practiced these skills on the computer in each training session after the discussion.

Participants in the speed of processing training condition discussed topics such as mobility, including falling and driving, and how speed of processing ability is related to such activities. These participants practiced computerized tasks at increasingly complex levels with central tasks alone (indicating presence or absence of targets, identifying targets, performing same/different discriminations of targets) or combinations of central and peripheral tasks (localizing targets at varying eccentricities) at decreasing (faster) presentation speeds (from 500 to 17 ms). Difficulty of the training tasks was changed by gradually increasing the complexity of the central task, the peripheral task, or both while display speed was held constant. Once 75% mastery of a particular task was achieved, display speed was decreased. This process was repeated until mastery of a particular task was achieved at the briefest display duration. Then task complexity was increased, and the process of modifying display speed was repeated. Overall, the goal of these training techniques was to gradually increase task difficulty (complexity and speed) at levels tailored to the individual until mastery was achieved through practice.

Results

The pre- and post-training data were examined for outliers and missing data points. Less than 0.5% of the data points were identified as outliers, defined as ± 3.5 z. Each of these data points was recoded to t score equivalent to ± 3.5 standard deviations from the mean. Less than 0.5% of the data points were missing. All of the missing data points were substituted such that pre and post-training scores were equivalent. This is a conservative approach that assumes no training effect. Thus, if the pre-training score was missing, the post score was assigned. If the post-training score was missing, the pre score was assigned. Regression equations were used to impute pre- and post-training Stroop scores for one case in which both data points were missing.

Seventy-six percent of participants attended all 10 training sessions. On average, participants across both conditions completed 9.6 sessions of training. No participant attended less than eight training sessions; thus all were included in analyses.

The speed and Internet training groups were compared by Multivariate Analysis of Variance (MANOVA) to examine if there were any baseline differences. There were no group differences in age, education level, or average number of participants in training sessions, Wilks' $\Lambda = 0.97$, F (3, 122) $= 1.27$, $p = 0.289$. Neither were there any baseline differences between the two groups in sensory abilities as indicated by far visual acuity, contrast sensitivity, and hearing, Wilks' $\Lambda = 0.983$, F (3, 122) < 1, $p = 0.555$. Descriptive statistics are presented by group in Table I.

Table I. Means and standard deviations for demographic and inclusion variables.

	Speed ($n = 63$)		Internet ($n = 63$)	
Measure	M	SD	M	SD
Age (years)	75.42	5.93	75.85	6.03
Education (years)	13.81	2.55	13.10	2.25
Average number of participants in training session	2.01	0.68	2.09	0.73
Far Visual Acuity (0–90)	67.92	13.24	66.27	13.85
Pelli Contrast Sensitivity (log contrast)	1.63	0.16	1.62	0.15
Hearing (average threshold in dB)*	26.26	12.30	28.98	11.04
Mini-Mental Status Exam (0–30)	28.22	1.39	28.00	1.76

Multivariate Analysis of Covariance (MANCOVA) was used: (1) to examine whether there were any baseline differences between the groups in cognitive and functional performance; and (2) to explore whether prior computer experience influenced performance. The dependent variables were MMSE, UFOV®, Digit Symbol Substitution, Letter and Pattern Comparison, Stroop, Trails A and B, Digit and Spatial Span, RST, and Timed IADL. Descriptive statistics for these measures are presented in Table II. No significant baseline differences in cognitive and functional performance were found, Wilks' $\Lambda = 0.916$, $F(15, 109) < 1$, $p = 0.848$. Neither was computer experience a significant covariate, Wilks' $\Lambda = 0.987$, $F(15, 109) < 1$, $p = 0.474$.

To examine the impact of speed of processing training relative to the Internet training control group, a repeated measures MANCOVA was conducted comparing the two groups' overall performance across testing occasions while controlling for education. Eleven dependent cognitive (UFOV®, Letter and Pattern Comparison, Digit Symbol Substitution (corrected by Digit Copy), Stroop, Trails A and B, Digit and Spatial Span) and functional measures (RST, Timed IADL) across the two visits were examined. Results revealed a significant interaction between testing occasion and condition, Wilks' $\Lambda = 0.578$, F (11, 113) = 7.51, $p < 0.001$. In order to investigate this significant interaction further, the MANCOVA was followed up with 11 univariate ANCOVAs. In each of these ANCOVAs, both: (1) pre-training performance for the cognitive dependent variable analyzed; and (2) education were entered as covariates. Group membership was the independent variable and post-training performance was the dependent variable. After adjustment for pre-training UFOV® performance and education level, a significant main effect of group was found for post-training performance on the UFOV® measure, F (1, 122) = 92.50, $p < 0.001$. Pre-training UFOV® performance was a significant covariate, $F(1, 122) = 58.18$, $p < 0.001$, but education was not, $F(1, 122) < 1$, $p = 0.518$. After controlling for pre-training UFOV® performance and education, those who completed speed of processing training performed significantly better post-training on the UFOV® than did the Internet control group.

A significant main effect of group was also found for Timed IADL post-training performance, $F(1, 122) = 4.95$, $p = 0.028$. Pre-training performance was a significant covariate for post-training Timed IADL performance, $F(1, 122) = 66.15$, $p < 0.001$, but education was not, $F(1, 122) < 1$, $p = 0.338$. Overall, after adjusting for pre-training Timed IADL performance and education, the speed-trained group performed more quickly and accurately on the Timed IADL task post-training than did the internet-trained group.

No other significant main effects of group were found (p's > 0.05). Pre-training performance was a significant predictor of post-training performance for all of the other dependent variables (p's < 0.001) and education was a significant covariate for Letter Comparison and Spatial Span (p's < 0.05). Pre- and post-training means and standard deviations are presented in Table II.

Using the formula described by Dudek, the amount of change needed to constitute reliable improvement in the intervention group was calculated by subtracting out the practice effects experienced by the control group (Dudek, 1979). Ninety percent (57/63) of the speed of processing trained participants demonstrated reliable training gain in speed of processing as indicated by pre- to post-training UFOV® performance relative to the gains of the control group.

In a recent study (Edwards et al., 2002), the magnitude of the training effect, measured by the amount of pre- to post-change in the nearest transfer measure, UFOV®, was smaller (0.62 SD improvement) than was expected based upon past research (Roenker et al., 2003); 2.5 SD improvement. In the present study, the training effect for the

Table II. Means and standard deviations for cognitive measures across assessments.

	Speed ($n = 63$)				Internet ($n = 63$)			
	Pre		Post		Pre		Post	
Cognitive and Everyday Measures (possible range)	M	SD	M	SD	M	SD	M	SD
Useful Field of View (64–2000 ms)*	1093.62	217.71	669.54	213.28	1118.60	221.35	1007.54	240.65
Road Sign Test (average reaction time s)*	2.11	0.59	1.87	0.49	2.23	0.74	2.23	1.36
Timed IADL (composite *z*-score)*	−0.02	0.51	−0.10	0.48	0.02	0.62	0.12	0.81
Letter Comparison (0–160)	37.57	7.94	39.03	8.68	35.63	8.92	36.73	7.69
Pattern Comparison (0–96)	25.46	5.30	27.24	5.73	24.06	5.63	25.43	5.49
Digit Symbol Substitution (items substituted/s)	1.42	0.58	1.41	1.01	1.53	0.67	1.54	0.86
Stroop (stroop effect score with error correction)*	37.19	17.22	34.48	16.76	45.29	25.29	39.64	23.44
Trails A (time in s)*	47.22	16.70	45.03	16.02	55.62	24.63	52.37	24.36
Trails B (time in s)*	145.39	80.46	132.98	71.82	177.74	123.01	165.18	95.70
Digit Span (0–16)	9.49	1.92	9.64	1.95	8.97	1.91	9.11	2.01
Spatial Span (0–16)	6.90	1.71	7.03	1.67	6.90	1.52	7.05	1.77

*Smaller scores reflect better performance.

speed-trained participants was 1.94 standard deviations of improvement on UFOV®, an effect of similar magnitude to original findings. It was not clear in the Edwards et al. (2002) study whether the smaller magnitude of training transfer was due to the use of a group-training format as compared to the individual training format used in the Roenker et al. (2003) study. Therefore, participants in the present study who were speed trained individually ($n = 17$) were compared to those who were speed trained in groups ($n = 46$), in order to examine whether group versus individual training differentially impacted training gain. No significant differences in training gain were found based upon group versus individual training methods, $F(1, 61) < 1$, $p = 0.449$ (individual M = 393 ms gain; group M = 435 ms gain). Thus, participants in the speed of processing training condition improved to an equivalent degree whether they were trained in groups or individually.

Discussion

The present study re-examined the magnitude of training gain and extent of transfer of a speed of processing intervention in a sample selected for initial processing speed difficulty. Individuals with intact mental status, adequate vision and hearing, and speed of processing difficulty were randomized to speed of processing or Internet training. Results indicate that relative to a social- and computer-contact control group, speed of processing trained individuals demonstrate improved performance on the UFOV® test and transfer to improved performance on a measure of Timed IADL. These results replicate and extend previous findings.

The transfer of training to performance of Timed IADL partially supports our hypothesis that transfer would be evident on tasks other than UFOV® in a sample of older adults with initial speed of processing difficulty. The transfer found in this study is encouraging, in that the Timed IADL measure closely emulates tasks performed in everyday life. The results only partially support our hypothesis, however, in that transfer to other cognitive measures and to functional measures other than Timed IADL were not found. This raises the question of why, across studies with the computerized speed of processing training protocol, transfer has been found to Timed IADL, RST (when administered in a driving simulator as in Roenker et al., 2003), and to on-the-road driving performance, but training has not improved performance on other cognitive measures such as Letter and Pattern Comparison, Trails A and B, or Stroop. We contend that Timed IADL and the RST (particularly when administered in a driving simulator) simulate tasks performed in everyday life. The RST simulates aspects of driving with the identification of and appropriate reaction (turning the steering wheel or braking) to particular road signs. Furthermore, Timed IADL involves tasks performed in everyday life such as looking up phone numbers, counting out change, and reading medicine bottles. In comparison tasks such as Letter and Pattern Comparison, Stroop, and Trails A and B are more abstract, laboratory-based measurements of cognitive function. Thus, transfer of speed of processing training is more evident in measures that are similar to tasks performed in everyday life, demonstrating the ecological validity of the training.

The training effect size in this sample was greater than that found those in prior studies that included individuals without speed of processing difficulty (Ball et al., 2002; Edwards et al., 2002). These findings indicate that the lack of immediate transfer of the speed of processing intervention to functional outcomes in the ACTIVE study (Ball et al., 2002) may have been due to inclusion criteria and ceiling effects. In other words, individuals with initial speed of processing difficulty may be more likely to widely benefit from the intervention. These findings do not contradict the ACTIVE study; in fact, although immediate transfer to a composite of everyday speeded performance (which included Timed IADL) was not found in ACTIVE, transfer was found at an annual assessment for speed of processing trained participants who received booster training sessions (Ball et al., 2002).

Both individual and group training methods were used in this study. The results supported our hypothesis that the format of training did not differentially impact training gain. The control group involved in this study experienced the same amount of social contact and the same amount of computer contact, as did the intervention group. Therefore, neither increased computer experience nor social contact are viable explanations for the training gains experienced through the speed of processing intervention.

The current research speaks to several points raised in cognitive training literature. Varied methods of improving cognitive function in older adults have been tried and found to be effective in enhancing specifically targeted abilities. These studies have used formats such as one on one tutoring (Rasmusson, Rebok, Bylsma & Brandt, 1999), self-guided practice (Baltes, Sowarka & Kliegl, 1989), group training on strategies for problem solving (Blieszner, Willis & Baltes, 1981) or memory enhancement (Schmitt, Murphy & Sanders, 1981), providing basic performance feedback (Blackburn, Papalia-Finlay, Foye & Serlin, 1988), and providing extended practice time (Dittmann-Kohli, Lachman, Kliegl & Baltes, 1991). Results of such varied approaches show that older adults seem able to benefit from virtually any effort to improve their basic cognitive abilities. While these various techniques have divergent records of accomplishment when it comes to demonstrating transfer to untargeted cognitive abilities, they all point to the amazing plasticity that older adults retain.

Effectiveness of training may be measured as narrowly as improvement on a single task that was specifically trained or as broadly as testing for transfer from a specific trained ability to improved performance on tests of diverse cognitive and functional abilities. Substantiating transfer of training to other untrained cognitive abilities and especially to functional abilities has been difficult to achieve thus far. Studies of training interventions for basic cognitive abilities, while they may intuitively seem likely to improve everyday functional abilities as well, rarely find such broad transfer of training. One reason for the lack of significant findings may be that everyday abilities are slower to decline than are basic cognitive abilities. In a seven-year longitudinal study of everyday abilities, Willis found that participants' IADL performance did not begin significant decline until they reached their late 70s and 80s (Willis, 1996). Additionally, as Fisk and Rogers (2000) have noted, older adults, despite declines in cognitive ability that accompany aging, show little if any decline in the performance of many well learned skills. Therefore, it may be that few participants in typical cognitive training studies are at serious risk for immediate functional decline and are therefore unlikely to show any benefit (because there is little room for benefit).

In summary, speed of processing training is immediately beneficial for older adults who evidence speed of processing difficulty. The training both improves UFOV® performance and transfers to Timed IADL performance, a speeded task that simulates cognitively demanding everyday activities integral to independent living. Of course, it is important to consider that the present study only examined immediate transfer of training. Longitudinal studies may indicate that such training is also preventive or protective against decline for older adults without speed of processing difficulty. Even so, research to date indicates that immediate transfer of the training to other tasks is most evident in older adults with speed of processing difficulty. Further research is needed to investigate the long-term impact of this training and to examine the transfer of training to other everyday tasks.

References

Ball, K., Beard, B., Roenker, D., Miller, R., & Ball, D. (1988). Visual search: Age and practice. *Investigative Ophthalmology and Visual Science, 29*, 448.

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., Morris, J., et al. (2002). Effects of cognitive training interventions with older adults. A randomized controlled trial. *The Journal of the American Medical Association, 288*, 2271–2281.

Ball, K., & Owsley, C. (1993). The useful field of view test: A new technique for evaluating age-related declines in visual function. *Journal of the American Optometric Association, 64* (*1*), 71–79.

Ball, K., & Owsley, C. (2000). Increasing mobility and reducing accidents of older drivers. In K. W. Schaie & M. Pietrucha (Eds.), *Mobility and transportation in the elderly* (pp. 213–251). New York: Springer Publishing Company, Inc.

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Visual Science, 34* (*11*), 3110–3123.

Ball, K. K., Beard, B. L., Roenker, D. L., Miller, R. L., & Griggs, D. S. (1988). Age and visual search: Expanding the Useful Field of View. *Journal of the Optical Society of America. A, Optics, Image Science, and Vision, 5* (*12*), 2210–2219.

Baltes, M. M., Kuhl, K., & Sowarka, D. (1992). Testing for limits of cognitive reserve capacity: A promising strategy for early diagnosis of dementia? *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 47*, 165–167.

Baltes, P. B., Sowarka, D., & Kliegl, R. (1989). Cognitive training research on fluid intelligence in old age: What can older adults achieve by themselves? *Psychology and Aging, 4* (*2*), 217–221.

Baltes, P. B., & Willis, S. L. (1982). Plasticity and enhancement of intellectual functioning in old age: Penn State's Adult Development and Enrichment Project (ADEPT). In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 353–390). New York: Plenum Press.

Beres, C. A., & Baron, A. (1981). Improved digit symbol substitution by older women as a result of extended practice. *Journal of Gerontology, 36* (*5*), 591–597.

Birren, J. E., Woods, A. M., & Williams, M. V. (1980). Behavioral slowing with age: Causes, organization, and consequences of slowing. In L. W. Poon (Ed.), *Aging in the 1980s: Psychological issues* (pp. 293–308). Washington, DC: American Psychological Association.

Blackburn, J. A., Papalia-Finlay, D., Foye, B. F., & Serlin, R. C. (1988). Modifiability of figural relations performance among elderly adults. *Journal of Gerontology: Psychological Sciences, 43* (*3*), P87–P89.

Blieszner, R., Willis, S. L., & Baltes, P. B. (1981). Training research in aging on the fluid ability of inductive reasoning. *Journal of Applied Developmental Psychology, 2*, 247–265.

Caprio-Prevette, M. D., & Fry, P. S. (1996). Memory enhancement program for community-based older adults: Development and evaluation. *Experimental Aging Research, 22*, 281–303.

Czaja, S. J., & Sharit, J. (1998). Age differences in attitudes toward computers. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 53B* (*5*), P329–P340.

Dittmann-Kohli, F., Lachman, M. E., Kliegl, R., & Baltes, P. B. (1991). Effects of cognitive training and testing on intellectual efficacy beliefs in elderly adults. *Journal of Gerontology, 46* (*4*), P162–P164.

Dudek, F. J. (1979). The continuing misinterpretation of the standard error of measurement. *Psychological Bulletin, 86*, 335–337.

Edwards, J. D., Wadley, V. G., Myers, R. S., Roenker, D. L., Cissell, G. M., & Ball, K. K. (2002). Transfer of a speed of processing intervention to near and far cognitive functions. *Gerontology, 48*, 329–340.

Fisk, A. D., & Rogers, W. A. (2000). Influence of training and experience on skill acquisition and maintenance in older adults. *Journal of Aging and Physical Activity, 8*, 373–378.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12* (*3*), 189–198.

Hayslip, B., Maloy, R. M., & Kohl, R. (1995). Long-term efficacy with fluid ability interventions with older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 50B*, P141–P149.

Jobe, J. B., Smith, D. M., Ball, K., Tennstedt, S. L., Marsiske, M., Willis, S. L., et al. (2001). ACTIVE: A cognitive intervention trial to promote independence in older adults. *Controlled Clinical Trials, 22* (*4*), 453–479.

Katz, J. (1985). *Handbook of clinical audiology*. Baltimore: Williams & Wilkins Co.

Kausler, D. H. (1994). *Learning and memory in normal aging*. New York: Springer.

Kramer, A., Larish, J. F., & Strayer, D. L. (1995). Training for attentional control in dual task settings: A comparison of young and old adults. *Journal of Experimental Psychology: Applied, 1* (*1*), 50–76.

Kramer, A. F., & Willis, S. L. (2002). Enhancing the cognitive vitality of older adults. *Current Directions in Psychological Science, 11* (*5*), 173–177.

Lezak, M. D. (1995). *Neuropsychological assessment* (*Third Edition*). New York: Oxford University Press.

Mohs, R. C., Ashman, T. A., Jantzen, K., Albert, M., Brandt, J., Gordon, B., et al. (1998). A study of the efficacy of a comprehensive enhancement program in healthy elderly persons. *Psychiatry Research, 77*, 183–195.

Myers, R. S., Ball, K. K., Kalina, T. D., Roth, D. L., & Goode, K. T. (2000). The relationship of Useful Field of View and other screening instruments to on-road driving performance. *Perceptual and Motor Skills, 91* (*1*), 279–290.

Neely, A. S., & Bäckman, L. (1995). Effects of multifactorial memory training in old age: Generalizability across tasks and individuals. *Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 50B*, P134–P140.

Oswald, W. D., Rupprecht, R., Gunzelmann, T., & Tritt, K. (1996). The SIMA-project: Effects of one year cognitive and psychomotor training on cognitive abilities of the elderly. *Behavioural Brain Research, 78*, 67–72.

Owsley, C., Ball, K., & Keeton, D. M. (1995). Relationship between visual sensitivity and target localization in older adults. *Vision Research, 35* (*4*), 579–587.

Owsley, C., Ball, K., McGwin, G J., Sloane, M. E., Roenker, D. L., White, M. F., et al. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. *The Journal of the American Medical Association, 279* (*14*), 1083–1088.

Owsley, C., Ball, K., Sloane, M., Roenker, D. L., & Bruni, J. R. (1991). Visual/cognitive correlates of vehicle accidents in older drivers. *Psychology and Aging, 6*, 403–415.

Owsley, C., McGwin, G., Jr., Sloane, M. E., Stalvey, B. T., & Wells, J. (2001). Timed instrumental activities of daily living (TIADL) tasks: Relationship to visual function in older adults. *Optometry and Vision Science: Official Publication of the American Academy of Optometry, 78* (*5*), 350–359.

Owsley, C., Sloane, M., McGwin, G., Jr., & Ball, K. (2002). Timed Instrumental Activities of Daily Living tasks: Relationship to cognitive function and everyday performance assessments in older adults. *Gerontology, 48*, 254–265.

Rasmusson, D. X., Rebok, G. W., Bylsma, F. W., & Brandt, J. (1999). Effects of three types of memory training in normal elderly. *Aging, Neuropsychology, and Cognition, 6*, 56–66.

Reitan, R. M. (1958). *Trail Making Test: Manual for administration, scoring and interpretation*. Indianapolis: Department of Neurology, Indiana University Medical Center.

Roenker, D. L., Cissell, G. M., Ball, K. K., Wadley, V. G., & Edwards, J. D. (2003). Speed-of-processing and driving simulator training results in improved driving performance. *Human Factors, 45* (*2*), 218–233.

Salthouse, T. A. (1991). Mediation of adult age differences in cognition by reductions in working memory and speed of processing. *Psychological Science: A Journal of the American Psychological Society / APS, 2*, 179–183.

Salthouse, T. A. (1992). What do adult age differences in the Digit Symbol Substitution Test reflect? *Journal of Gerontology, 47* (*3*), P121–P128.

Salthouse, T. A. (1995). Influence of processing speed on adult age differences in learning. *Swiss Journal of Psychology, 54*, 102–112.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103* (*3*), 403–428.

Salthouse, T. A., Hambrick, D. Z., & McGuthry, K. E. (1998). Shared age-related influences on cognitive and non-cognitive variables. *Psychology and Aging, 13*, 486–500.

Salthouse, T. A., & Meinz, E. J. (1995). Aging, inhibition, working memory, and speed. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 50B*, P297–P306.

Schaie, K. W. (1996). *Intellectual development in adulthood. The Seattle Longitudinal study*. New York: Cambridge University Press.

Schmitt, F. A., Murphy, M. D., & Sanders, R. E. (1981). Training older adult free recall rehearsal strategies. *Journal of Gerontology, 36* (*3*), 329–337.

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press.

Stern, R. A., & Prohaska, M. L. (1996). Neuropsychological evaluation of executive functioning. *Review of Psychiatry, 15*, 243–266.

Trenerry, M. R., Crosson, B., DeBoe, J., & Leber, W. R. (1989). *Stroop Neurological Screening Test*. Lutz, FL: Psychological Assessment Resources.

Tun, P. A., Wingfield, A., & Lindfield, K. C. (1997). Motor-speed baseline for the Digit-Symbol Substitution Test. *Clinical Gerontologist, 18* (*1*), 47–51.

Wechsler, D. (1981). *WAIS-R Manual*. New York: The Psychological Corporation.

Willis, S. L. (1996). Everyday cognitive competence in elderly persons: Conceptual issues and empirical findings. *The Gerontologist, 36* (*5*), 595–601.

Willis, S. L., Bliezner, R., & Baltes, P. B. (1981). Intellectual training research in aging: Modification of performance on the fluid ability of figural relations. *Journal of Educational Psychology, 73* (*1*), 41–50.

Willis, S. L., Cornelius, S. W., Blow, F. C., & Baltes, P. B. (1983). Training research in aging: Attentional processes. *Journal of Educational Psychology, 75* (*2*), 257–270.

Willis, S. L., Jay, G. M., Diehl, M., & Marsiske, M. (1992). Longitudinal change and prediction of everyday task competence in the elderly. *Research on Aging, 14* (*1*), 68–91.

Willis, S. L., & Schaie, K. W. (1994). Cognitive training in the normal elderly. In F. Forette & Y. Christen & F. Boller (Eds.), *Plasticité cérébrale et stimulation cognitive*. Paris: Fondation Nationale de Gérontologie.