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Speed of Processing Training in the ACTIVE Study: Who Benefits?

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Abstract

Objectives—Cognitive training has been shown to improve both cognitive and everyday abilities in older adults; however, little is known concerning the amount of training needed or the characteristics of those who benefit. These analyses examined the longitudinal impact of dosage (number of training sessions) on the improvement and maintenance of cognitive and everyday function.

Methods—ACTIVE is a longitudinal, randomized, single-blind clinical trial evaluating cognitive interventions in older adults (aged 65-94) from six states in the United States.

Results—Latent growth curve models indicated that initial training effects were maintained over 5 years and amplified by booster sessions. A single booster session counteracted 4.92 months of age-related processing speed decline.

Discussion—Cognitive performance improved by 2.5 standard deviations for participants who attended all 10 initial sessions and all 8 booster sessions compared to randomized participants who attended none. Implications for the broader application of cognitive training interventions are discussed.

Keywords

aging; activities of daily living; cognitive training; UFOV; driving

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Ten hours of speed of processing training (SOPT) has been shown to increase the processing speed of older adults across a 5 year period (Willis et al., 2006). Processing speed is assessed through performance on the Useful Field of View Test (UFOV[1]), a cognitively demanding measure of visual processing speed that predicts future vehicle crashes and other functional outcomes in older adults (Ball, Wadley, Vance, & Edwards, 2007). To date, there is little information on how much SOPT is required to be optimally effective, or whether subsequent booster sessions can improve or maintain cognitive and functional performance over an extended period of time. The present analyses focused on data from 702 older adults randomized to SOPT in the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study, to further examine the impact of initial and booster training on the maintenance of cognitive and everyday function.

A detailed review of research on SOPT is presented elsewhere. The ACTIVE SOPT protocol was developed from work by Ball and colleagues (Ball et al., 1988) who found that SOPT could enhance older adults' cognitive performance. SOPT is a nonverbal, computerized program that involves practice of visual and auditory tasks designed to enhance mental quickness. The training protocol is based upon principles of the UFOV test but is much more than merely practicing the test. A specified training program is followed by a qualified trainer in order for each trainee to achieve specific *individualized* processing speed goals for four speeded tasks. These four tasks are similar to the UFOV subtests, but include variations of target type (visual or auditory), location, conspicuity, and complexity with the primary manipulation throughout training being display speed. Through guided practice and feedback, the training aims to increase the speed and accuracy with which individuals can process information.

Considering that prior research by Ball and colleagues has shown that UFOV performance is indicative of older adults' ability to drive safely (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Ball et al., 2006; Owsley, McGwin, & Ball, 1998), early research with the SOPT protocol examined the efficacy of the program to improve driving competence. Roenker and colleagues found that individuals who completed SOPT experienced immediate improvements in UFOV performance and demonstrated safer on-road driving. Participants also demonstrated significantly faster responses in a driving simulator and reacted 277 ms more quickly to road signs presented in a visual-search display (Road Sign Test), such that they could stop a vehicle traveling at 55 mph 22-feet sooner than prior to training (Roenker, Cissell, Ball, Wadley, & Edwards, 2003). Recently, SOPT in ACTIVE was shown to protect against future crash risk, cutting the risk of at-fault state-reported crashes in half over the next 6 years (Ball, Edwards, Ross, & McGwin,2010). In addition, SOPT was protective against driving cessation with trained participants continuing to maintain their driving mobility longer than control participants (Edwards, Delahunt, & Mahncke, 2009; Edwards, Myers et al., 2009).

Further research with the SOPT protocol examined the extent to which training impacted other cognitive and everyday performance measures (Edwards, Ball, Wadley, & Wood, 2002). Similar to the results of other cognitive training studies (Kramer & Willis, 2002; Neely & Bäckman, 1995; Willis, Bliezner, & Baltes, 1981; Willis & Schaie, 1994) although training immediately improved UFOV performance, it did not improve performance in other cognitive domains such as reasoning and memory. However, the training did result in improved everyday performance measured with the Timed Instrumental Activities of Daily Living test (TIADL), which requires quick and accurate performance in looking up a telephone number, counting out correct change, finding food items on a crowded shelf, and

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reading medication labels (Edwards, Wadley et al., 2002; Edwards, Wadley, Vance, Wood et al., 2005).

The ACTIVE investigators hypothesized that SOPT would immediately enhance processing speed performance. If such cognitive training gains were observed and maintained, then everyday functioning would be enhanced or maintained; preserving the independence, health and quality of life of older adults. To test these hypotheses, the ACTIVE study included follow-up assessments at 1, 2, 3, and 5 years.

Results from the ACTIVE study to date have provided support for some of these hypotheses (Ball et al., 2002; Willis et al., 2006; Wolinsky, Unverzagt, Smith, Jones, Stoddard et al., 2006; Wolinsky, Unverzagt, Smith, Jones, Wright et al., 2006). Immediately posttraining, 87% of speed-trained participants experienced reliable improvement in the processing speed composite measure with a net effect size of 1.46 at immediate posttest and an effect size of 0.76 at Annual 5 as compared to the control group (Ball et al., 2002; Willis et al., 2006). There have also been positive results with respect to the impact of training on independence and quality of life. Two years after completing SOPT, trainees were between 30% and 38% less likely to experience a significant decline in health-related quality of life than were control participants (Wolinsky, Unverzagt, Smith, Jones, Wright et al., 2006). At the 5-year follow-up, SOPT participants continued to experience protection from decline in health-related quality of life as compared to control participants (Wolinsky, Unverzagt, Smith, Jones, Stoddard et al., 2006). SOPT participants have also reported fewer depressive symptoms and maintained self-reported health (Wolinsky, Mahncke, Vander Weg et al., 2009; Wolinsky et al., 2010; Wolinsky, Vander Weg et al., 2009).

Booster sessions were also included in the ACTIVE study at Annuals 1 and 3 (see the overview paper in this issue for the ACTIVE study design). SOPT participants who received booster training after 1 year demonstrated a net effect size of 0.92 at first and 0.35 at second annual follow-up, respectively on an everyday speed composite (TIADL and Road Sign Test). These boosted SOPT participants maintained significant improvements on this everyday speed composite after 5 years (Willis et al., 2006).

Based on the ACTIVE findings to date, natural follow-up questions arise. Specifically, “How much training is needed?” and “Who benefits from this training?” In the present analyses, we constructed longitudinal models that sought to separate and estimate the speed of processing improvements due to initial training and booster training among the 702 ACTIVE participants originally randomized to SOPT. Our model took into account effects of demographics (age, gender, education), mental status, and baseline health status. After confirming the effects of booster training using an intention-to-treat (ITT) approach, we then sought to determine whether the amount of training received was related to the degree of speed of processing gain. This is important because it has been suggested that in at least some instances, cognitive training gains may be explained by familiarization, practice, enhanced self-efficacy, or reduced anxiety rather than improvement in cognitive ability (Hayslip,1989). However, familiarization with training and initial practice effects, which are frequently observed, would be expected to have less impact in booster sessions since participants are already familiar with training and have already achieved benefits. In addition, the transfer of SOPT and booster sessions onto measures of everyday speed, such as the Road Sign Test and TIADL, were investigated through both the treatment received and the ITT models to determine whether degree of training was also related to these more distal outcomes.

Method

Participants

Data from the longitudinal, randomized, single-blind clinical trial ACTIVE were analyzed to address these questions. The ACTIVE study included adults aged 65 to 94 years of age from 6 states throughout the United States. Participants were excluded if there was evidence of substantial cognitive (MMSE <23 or diagnosis of dementia), visual (self-report of excessive difficulty reading newspaper print or visual acuity worse than 20/50), or functional impairments (difficulty with ADLs), or if an individual reported a diagnosis of a medical condition that would predispose him or her to possible functional decline or mortality, such as stroke or cancer. All participants signed an IRB (institutional review board)-approved informed consent and were treated in compliance with the Helsinki Declaration and APA ethical standards. Further details regarding ACTIVE are provided elsewhere (Jobe et al., 2001; Willis et al., 2006).

The current analyses are based on the 702 persons who were randomized to SOPT. At baseline these participants ranged in age from 65 to 91 years (*M*= 73, *SD*=5.8) and had an average level of education of 13.7 years (range 5 to 20 years).

Procedure

After a telephone-screen, eligible participants consented to in-person baseline assessments of sensory, cognitive, health, everyday habits, and functional abilities. Participants were then randomized to either a no-contact control group (*n*=704), SOPT group (*n* = 712), memory training group (*n* =711), or reasoning training group (*n* =705). However, due to an error in randomization, 30 participants (10 from the SOPT arm) were dropped from analyses. This resulted in a total sample of 2,802 persons, with 702 assigned to the SOPT group.

Eligible participants (those who completed at least 80% of the training) in each of the three training arms were subsequently randomized into booster or non-booster groups just prior to first annual follow-up evaluations. A total of 633 of the 702 (90.2%) SOPT participants met this eligibility requirement. Of these, 365 (57.7%) were randomized to booster training and 268 (42.3%) were randomized to no-booster. Table 1 summarizes the demographic information for the three subgroups of SOPT participants from ACTIVE (assigned to *booster*, assigned to *no-booster*, and *not eligible* to be assigned).

Those randomized to booster were invited to complete four additional SOPT sessions (one-and-a-half hours in duration each) 1 month prior to the first and third annual assessment (total of eight possible booster sessions). Of the participants randomized to booster, 75.9% (n=277) received all four of the booster sessions at Annual 1, and 60.0% (*n*=219) received all four booster sessions at Annual 3. Follow-up assessments were conducted immediately after training as well as at 1, 2, 3, and 5 years post-training. The number of participants who completed such assessments were 643 (91.6%), 539 (76.8%), 499 (71.1%), 464 (66.1%), and 404 (57.5%), respectively.

Materials

The UFOV Test—UFOV is a computerized measure of visual information processing speed consisting of four subtests that increase in cognitive complexity. It is important to note that the UFOV test is not a pure measure of speed of processing as any speed of information processing measure taps multiple cognitive and sensory abilities as well. The PC (touch) version of the test, which has test-retest reliability of 0.74, was administered (Edwards et al., 2006; Edwards, Vance et al., 2005).

In each subtest, visual targets are presented at display durations between 16 and 500 ms. The 75% correct threshold of performance (display speed in ms) is determined for each subtest via the double-staircase method. The first subtest requires identification of a central target against an otherwise black background. The second subtest requires both central target identification and simultaneous localization of a peripheral target. This peripheral target is at a fixed eccentricity of 12.5 cm from the center target and is presented at one of eight radial locations from the central target. The third subtest requires both of these tasks with the addition of distractors surrounding the peripheral target. The fourth subtest requires discrimination of two central targets as same or different along with the simultaneous localization of a peripheral target in the presence of the distractors. Scores on each subtest represent the threshold display duration in ms at which the participant can perform the task correctly 75% of the time. A UFOV composite score was calculated across Subtests 2 to 4; Subtest 1 was not included because participants scored very well on this subtest at baseline (*M*= 30.66, *SD* = 40.51) with more than half performing at ceiling (16 ms; Edwards et al., 2006). Higher UFOV scores indicate longer processing times (poorer cognitive functioning).

Mini-Mental State Exam (MMSE)—The MMSE (Folstein, Folstein, & McHugh, 1975) assesses orientation, attention, language, memory and construction skills and has been widely used as a measure of general mental status to screen for dementia. Scores range from 0 to 30, with lower scores reflecting poorer functioning. As persons with an MMSE score lower than 23 at screening were excluded from ACTIVE; the resulting range within this sample was truncated, ranging from 23 to 30.

Self-Rated Health—Participants were asked the self-rated health item ("In general, would you say your health is") of the SF-36 (Ware & Sherbourne, 1992). Responses were collected using a 5-point scale (1 = *Excellent*, 5 = *Poor*).

Road Sign Test—This is a computerized complex reaction time test of relevant to everyday life that requires participants to ignore certain road signs (inhibit their response) and react to other road signs. Various combinations of four types of road signs in sets of three or six signs are flashed on the screen in varying positions. Participants are instructed to ignore any road signs with a red slash and to either click (in response to bicycle or pedestrian signs) or move the mouse (in response to arrow signs) in the appropriate direction to signs without slashes. The amount of time taken to correctly react to signs without slashes is recorded for both the three-and-six-stimuli presentations. The average of the three-and-six-stimuli scores was used in the present analyses with higher scores indicating poorer (slower) performance.

TIADL—This test assesses the speed and accuracy at which participants can perform five tasks relevant to everyday life. While most IADL measures focus on accuracy of performance, speed id also important for several reasons. We live in a society where information is often presented quickly, and successful adaptation depends on time-limited reactions. In everyday life there are clear advantages to performing activities more quickly. For example, when renewing prescriptions y phone, if an individual responds too slowly the telephone menu will often hang up. Long completion times can also be a source of frustration, inconvenience, and embarrassment. Slow processing may also be related to safety (e.g.. while driving). The five tasks include using a phone book, reading food and medication labels, finding an item on a crowded pantry shelf, and counting change. Standard test administration and scoring was used (Owsley, Sloane, McGwin, & Ball, 2002). Follow-up scores were standardized by the baseline *M* and *SD*.

The UFOV composite score and the Road Sign Test score were subjected (along with all other primary ACTIVE outcome variables) to a Blom transformation (Blom, 1958). This transformation applies the z-score from the standard normal distribution to the percentile of each raw score relative to the sample distribution at baseline. Thus, a normally distributed outcome variable is assured if there are no ties in the data. For the TIADL measure, z scores were calculated by subtracting the baseline mean and dividing by the baseline standard deviation. In addition, these z scores for UFOV, the Road Sign Test, and TIADL were further rescaled to have a total sample mean of 100 and a standard deviation of 10 at baseline.

SOPT—This is a computerized cognitive intervention aimed at enhancing older adults' mental processing speed such that increasingly more complex information can be processed over briefer periods of time (Ball, Edwards, & Ross, 2007). Training primarily involves practice, although some strategies are suggested by the trainer. Groups of 2 to 4 individuals attended up to10 training sessions (approximately 90-minutes each) guided by a certified trainer. The training tasks involve at least three basic levels of complexity that are similar to the first three subtests of the UFOV assessment. However, training involves much more than merely practicing the test. In training, all features of task difficulty (e.g., center task difficulty, modality of central task, eccentricity of the targets, conspicuity of the target and distractors) are adapted to produce at least 18 different tasks. As an example, whereas the UFOV Subtests 1 to 3 involve a center task of identifying a visual target, in training the center task is changed to be easier (target detection) or more difficult (performing a visual discrimination concurrent with an auditory task) based on the individual's performance. In the ACTIVE study, practice of tasks was standardized in Sessions 1 to 5 and customized to the performance level of each participant in sessions 5 to 10 (in order to achieve a relatively stable level of 75% correct performance).

Analyses

Latent growth curve modeling (LGM) was used to examine the effects of the booster training sessions and other determinants of speed of processing changes over time. All analyses were conducted using version 5.1 of the Mplus analysis system (Muthen & Muthen, 2007). We conducted two types of analyses, an intention-to-treat (ITT) analysis of the booster training condition, and a treatment-received analysis based on the actual number of intervention training and booster training sessions attended. Our primary outcome variable of processing speed was the UFOV composite measure. Additional models were performed on the Road Sign Test and TIADL measures of functional performance.

The ITT analyses conservatively estimated whether booster training had any significant effect before taking into account individual differences in compliance with booster training. The treatment-received analysis allowed us to test and quantify whether the benefits of training varied according to how much training was received. In both types of analyses, latent intercept and linear slope factors were specified to account for individual differences in overall level of processing speed and gradual change in processing speed. Participant age, education, gender, baseline MMSE, and self-rated health were included as predictors to account for the effects of these variables on performance level at the beginning of the study (Intercept) and the linear rate of change for each individual across time (Slope). Age, education, MMSE, and self-rated health were centered on their respective sample means, and gender was coded as 1 for women and 0 for men.

Effects for the initial training and the booster effects were then added as additional predictors of observed outcomes after controlling for the effects of the latent intercept and linear slope factors (and their predictors/covariates). All models were estimated using the

maximum likelihood method as provided by the TYPE-MISSING subcommand in Mplus. These estimates and their standard errors were used to test whether the observed training and booster effects were significantly different from zero. Full information maximum likelihood estimation was used based on all observations and variables in the model.

The ITT model for booster training is illustrated in Figure 1. This analysis is based on the 633 speed-of-processing participants who were initially compliant with training (e.g., attended at least 8 of the 10 initial training sessions) and who were subsequently randomized to either booster training (n = 365 or 58%) or no booster training (n = 268 or 42%). Randomization was weighted somewhat toward booster because in the primary analysis (reported elsewhere) those non-compliant with initial training were all included in the no-booster group. All factor- loading paths indicated from the intercept to the observed variables listed at the top of Figure 1 were fixed at 1.0. For the linear slope factor, the fixed factor loadings were 0.23 (posttest), 1.23 (Annual 1), 2.23 (Annual 2), 3.23 (Annual 3), and 5.23(Annual 5) to represent the amount of time in years that elapsed between baseline and each assessment point. The latent intercept and linear slope factors were then analyzed as effects of four continuous covariates (age, MMSE, education, and self-rated health at baseline) and the dichotomous covariate of gender. A coded indicator for booster randomization (1 for those randomized to booster training, 0 for those who were randomized to no booster training) was added as an additional predictor of cognitive performance beyond that accounted for by the intercept and linear slope factors and their covariates. Effects a and b in Figure 1 illustrate that ITT booster effect estimates were constrained to equal the same value (a) at year 1.23 and 2.23 and a different value (b) at year 3.23 and 5.23. This takes into account the additional booster sessions made available prior to the third year of follow-up testing.

The treatment-received model is an analysis of the number of sessions attended as a continuous predictor variable is illustrated in Figure 2. This analysis is based on all 702 participants who were randomized to receive SOPT and includes similar latent intercept and slope growth factors as the ITT analysis. The initial training effect was estimated by adding an observed variable for the number of initial training sessions attended (range 0-10) with effects free to be estimated on the dependent variables observed after training (effects c-g in Figure 2). In addition, the booster effects were divided into number of booster sessions attended at Annual 1 (range= 0-4), and the total number of sessions attended across Annual 1 and Annual 3 (range=0-8). This had the effect of making booster attendance a time-varying predictor among those assigned to that condition. Effects of Annual 1 booster attendance were estimated on Year 1.23 and 2.23 performance (Effects h and i in Figure 2), and total booster attendance effects were estimated on Year 3.23 and 5.23 performance (Effects j and k in Figure 2). The same background latent intercept and linear slope factors were identified and analyzed as effects of the same baseline covariates as those used in the ITT model.

In order to compare the effects of initial training sessions and booster training sessions, additional treatment-received models were constructed that constrained the training effects across time to be equal (Effects c, d, e, f, and g in Figure 2) and the booster effects across time to be equal (Effects h, i, j, and k in Figure 2). This resulted in “average” training and booster effects per session and facilitated comparisons of effect magnitude.

Because ACTIVE included six different study sites and six different replicate samples, the possible effects of site and replicate on training gain were investigated in supplemental longitudinal analyses. Including site and replicate in the models did not alter the findings. Consequently, site and replicate were not included as variables in the final models.

Results

Intention-to-Treat Analyses of Booster Effects

The ITT analysis indicated that randomization to the booster condition resulted in significantly improved UFOV performance. Both the 1-year and 3-year booster effects were found to be statistically significant (see Table 2 and Figure 1). Because the outcome variable was standardized to have a baseline standard deviation of 10, these estimates represent approximately one fifth of a standard deviation of improvement at the 1-year and 2-year assessments and more than two thirds of a standard deviation of improvement at the 3-year and 5-year assessments. The additional size of the effect on 3-year and 5-year performance is due to the additional booster sessions made available prior to the 3-year assessment.

Significant effects for randomization to booster training were also observed in the ITT model for the Road Sign Test. Both the 1-year and the 3-year booster effects were again statistically significant (see Table 2 and Figure 1). No significant ITT effects were observed, however, for TIADL.

Other effects of note in the ITT models include significant mean linear slopes across time for all three outcome variables (all p values $< .02$). These effects indicate that performance scores gradually worsened over time among those assigned to the no-booster condition. All of the covariate effects on the intercept latent factor were statistically significant ($p < .05$) with three exceptions. Gender did not have a significant effect on UFOV or the Road Sign test, and education did not have a significant effect on the UFOV latent intercept factor. Only one statistically significant effect was found for the covariates on the latent linear slope factor, with age affecting the slope factor for the Road Sign test (est. = 0.03, $SE = 0.01$, $p = .01$). These effects indicate that, after controlling for the other covariates in the model, the oldest participants showed more rapid increases (poorer performance) in the Road Sign test across time.

Treatment-Received Analyses

The treatment-received analyses that examined the effects for the number of training sessions received (initial and/or booster) as a continuous predictor, are summarized in Table 3.

For the number of initial training sessions, significant effects were observed at all five post-intervention assessment points for the UFOV test and at all assessments except the 5-year assessment for the Road Sign Test. Significant effects were obtained for TIADL at the 1-year and 2-year follow-up assessments ($p < .05$), with effects that approached conventional levels of significance at the post-intervention and 3-year assessments ($p < .07$). The number of booster sessions attended was also significantly related to performance over time at each follow-up assessment for both the UFOV test and the Road Sign Test after taking into account the initial training effects (Effects h-k; see Table 3 and Figure 2). No additional significant effects for booster sessions were observed for TIADL. The size of these training and booster effects for UFOV and the Road Sign Test indicate that while the initial training was somewhat attenuated over time, improvements related to initial 10 training sessions remained significant over the first 3 years (for Road Sign Test) or five years (for UFOV) regardless of whether booster sessions were attended. Booster sessions added additional significant improvement even after accounting for the effects of the initial training sessions. The effects were also substantially stronger for UFOV than for the Road Sign Test or TIADL.

The models that constrained the initial training effects per session to be equal over time and the booster attendance effects to be equal over time showed that the constant or general

effect of training sessions attended was statistically significant for all three outcome measures (UFOV: est.= -1.72, *SE* = 0.03, *p* <.0001; Road Sign Test: est. = -0.28, *SE* = 0.02, *p* <.0001; TIADL: est. = -0.06, *SE* = 0.02, *p* =.001). The constrained or general effect for booster sessions attended was statistically significant for UFOV (est.= -0.98, *SE* = 0.07, *p* <. 0001) and for the Road Sign Test only (est. = -0.26, *SE* = 0.05, *p* <.0001). For UFOV, the mean linear slope for those who attended no training or booster sessions was 2.39 points per year (*SE* = 0.16, *p* <.0001). The relative size of the UFOV estimates indicate that the gain from a single booster session was 0.57 times as large as the gain per initial training session (-0.98/-1.71) and reversed 41% of the processing speed decline observed per year after initial training (-0.98/2.39 = -0.41). This equates to 4.92 months of processing speed decline. For the Road Sign Test, the mean linear slope for those who attended no training or no booster sessions was only 0.33 points per year (SE = 0.13, *p* =.01). A single booster session, therefore, reversed 79% of the decline observed per year on this measure (-0.26/0.33 = -0.79) or 9.48 months of decline.

Model predicted values on the UFOV composite for participants who completed no training, participants who completed all 10 initial training sessions but no booster sessions, and participants who completed all 10 initial training and all 8 booster session are displayed in Figure 3. For participants who attended all 10 initial training sessions and all 8 booster training sessions, a predicted improvement of 2.50 standard deviations is indicated [(10 × -1.72/10) + (8 × -0.98/10)].

Discussion

The ACTIVE clinical trial differed from many earlier cognitive intervention studies in that it recruited a relatively healthy sample of older adults in an effort to focus on possible prevention of cognitive decline, rather than remediation of existing cognitive deficits (Willis et al., 2006). Although many papers have been published on the effectiveness of SOPT, the value of booster training was not known. As indicated by the latent intercept factor (Figure 2), persons with initially slower processing speed were older, had poorer cognitive functioning/MMSE, and poorer self-rated health. In addition, there were no significant covariate effects on the latent slope factor with the occasional exception for age, which sometimes indicated that older persons tended to experience greater declines across the five years of follow-up than younger participants. The current models illustrate the general declines in processing speed without training (slope) after taking into account individual differences such as age, education, gender, MMSE and health. Results reveal that SOPT is robust with the initial number of training sessions maintaining a training effect (increasing processing speed) over 5 years.

With respect to the question posed in the title of this paper, "Who benefits?" the analyses indicate that there are no differences in immediate training gain related to age, gender, education, mental status, or health status within the ranges recruited for ACTIVE. Similarly, training effects were maintained for participants assigned to cognitive training relative to controls, except for the tendency for the oldest participants to experience steeper declines over time than younger participants. Thus, within the range of the covariates in ACTIVE, it can be concluded that everyone benefits, irrespective of age, gender, education, MMSE, and health status, and that those who participate in the most training sessions receive the most benefit.

The current models indicate robust effects on improving processing speed as a result of booster training. This was evident in both the ITT analysis (Figure 1), which demonstrated that simply being randomized to booster training had a significant effect on increasing processing speed even before considering individual differences in compliance, and in

treatment-received analyses, which estimated the benefits of training regardless of randomization condition or individual differences in compliance. Interestingly, booster sessions added significant benefits on top of the gains already achieved by initial training, and a single booster session counteracted nearly 5 months of normative age-related decline in processing speed. This is exciting given the noninvasive nature of a 1-hr booster session in light of the negative effects of the age-related processing speed mechanism on cognition and its impact on daily functioning (Salthouse, 1996).

These analyses indicate that SOPT is a highly effective, noninvasive, and robust intervention with possible far-reaching implications. In accordance with other SOPT studies involving persons with reduced cognitive abilities (see Ball et al., 2007 for a review), the current model supports that this training is effective for many older persons with intact cognitive function. The potential of SOPT to positively impact older adults' lives is especially promising considering the relatively small amount of training time needed to attain such long-term effects.

With increasing longevity, and the growing percentage of older adults in the population, there is rising interest in helping older adults maintain cognitive fitness and a satisfying quality of life. Ultimately, the goal of cognitive training is to maintain cognitive function throughout the lifespan with a corresponding maintenance of everyday functioning. SOPT can immediately improve processing speed for many older adults, and booster training can provide additional benefits. While training results in enhanced performance of everyday activities and maintenance of health-related quality of life (Ball et al., 2010; Edwards et al., 2008; Edwards, Wadley et al., 2002; Edwards, Wadley, Vance, Roenker, & Ball, 2005; Wolinsky, Mahncke, Kosinski et al., 2009; Wolinsky et al., 2010; Wolinsky, Unverzagt, Smith, Jones, Stoddard et al., 2006; Wolinsky, Unverzagt, Smith, Jones, Wright et al., 2006), a needed area investigation is how to best disseminate such training to the older population. In summary, the ACTIVE clinical trial demonstrates that older adults are able to benefit from many approaches to improve cognitive function. Thus age-related decline in cognitive or everyday function need not be considered irreversible. The present analyses indicate that SOPT resulted in improved performance which was maintained over 5 years, and further increased by participation in booster training. While most certainly individuals age at different rates, and training benefits vary across individual participants, it is useful to put these results into context. On average, a single booster session counteracted nearly 5 months of normative age-related decline in UFOV and over 9 months of age-related decline on the Road Sign Test. Participants who participated in all training and booster sessions improved their processing speed, as measured by UFOV, by approximately 2.5 standard deviations. Initial efforts to disseminate SOPT cost-effectively are promising (Viamonte, Ball, & Kilgore, 2006), thus enhancing the potential for such training to improve the quality of life for older adults in the future.

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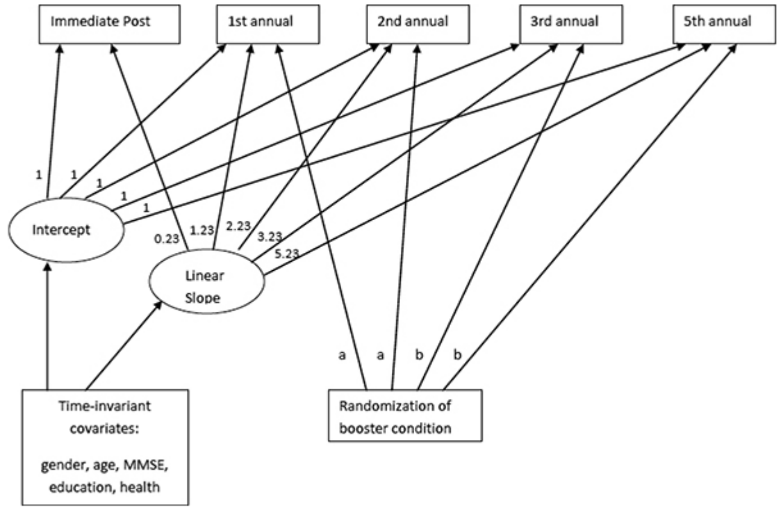

Figure 1.
Intent-to-Treat Analysis.
Latent growth curve model of the intent-to-treat analysis of the effect of randomization to booster training on processing speed.

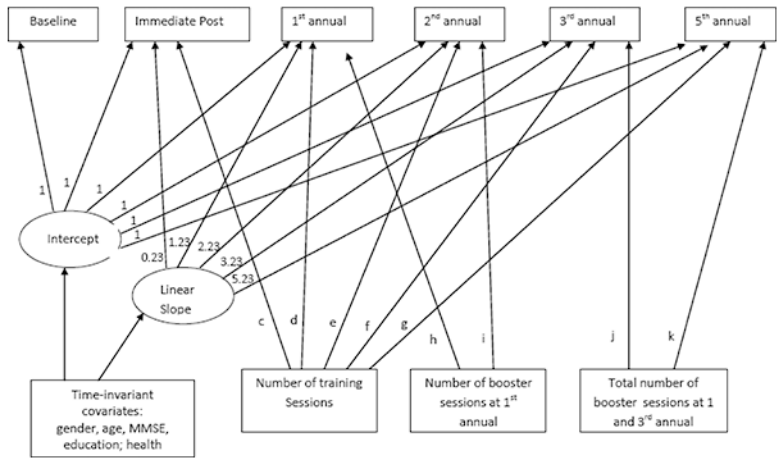

Figure 2. Treatment-Received Model

Latent growth curve model of the treatment-received model of the effect of initial training sessions and booster sessions on processing speed.

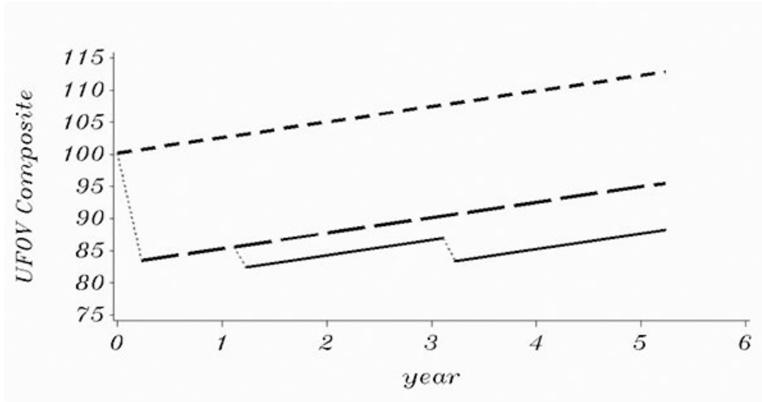

Figure 3. Model Predicted Scores

Model predicted scores of participants with no training, complete initial training only, and both initial training and booster training (which occurred prior to First and Third annual assessments).

Table 1

Demographics of Speed of Processing Training Participants Assigned to Either the Booster or No-Booster Condition

Covariates		Booster (*n* = 365)	No-booster (*n*= 268)	Not Eligible for Booster Assignment (*n* = 69)
Age	*M*	73.5	73.0	74.4
	Range	65-90	65-91	65-91
Years of education MMSE	*M*	13.6	13.7	13.4
	Range	5-20	5-20	7-20
	M	27.5	27.4	27.3
	Range	23-30	23-30	23-30
Female	*N*	280	203	55
	percentage	76.7	75.8	79.7

Note. MMSE= Mini Mental State Exam

Table 2

Effect Size Estimates and Standard Errors for the Intention-to-Treat Analyses (See Figure 1)

Outcome measures	Randomization to booster training group	
	a	**b**
UFOV	-2.13 (0.41)***	-6.76 (0.57)***
Road Sign Test	-1.04 (0.30)**	-1.72 (0.46)***
TIADL	0.05 (0.32)	0.36 (0.37)

Note. UFOV= Useful Field of View Test; TIADL = Timed Instrumental Activities of Daily Living Test. Effects are in Blom points for randomization to the booster training group.

* $p<.05$

** $p<.01$

*** $p<.001$

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Table 3

Effect Size Estimates and Standard Errors for the Treatment-Received Analyses (See Figure 2)

Outcome measures	Initial training effects					Booster effects			
	c	**d**	**e**	**F**	**g**	**h**	**i**	**j**	**k**
UFOV	-	-	-	-	-	-	-	-	-
	1.83***	1.23***	1.22***	1.11***	1.03***	2.15***	0.83***	1.25***	0.78***
	(0.04)	(0.06)	(0.09)	(0.12)	(0.18)	(0.14)	(0.16)	(0.09)	(0.10)
Road Sign Test	-	-	-0.19*	-0.20*	-0.06	-0.28*	-0.30*	-0.17*	-0.24**
	0.25***	0.21***	(0.07)	(0.10)	(0.16)	(0.11)	(.13)	(0.07)	(0.08)**
	(0.03)	(0.05)							
TIADL	-0.04	-0.07*	-0.11*	-0.13	-0.10	-0.12	-0.13	-0.01	-0.07
	(0.02)	(0.04)	(0.05)	(0.07)	(0.11)	(0.08)	(0.09)	(0.05)	(0.06)

Note. UFOV= Useful Field of View Test; TIADL = Timed Instrumental Activities of Daily Living Test. Effects are in Blom points per session attended.

* $p<.05$

** $p<.01$

*** $p<.001$