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An Examination of Mediators of the Transfer of Cognitive Speed of Processing Training to Everyday Functional Performance

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Abstract

The purpose of these analyses was to examine mediators of the transfer of cognitive speed of processing training to improved everyday functional performance (Edwards, Wadley, Vance, Roenker, & Ball, 2005). Cognitive speed of processing and visual attention (as measured by the Useful Field of View Test; UFOV) were examined as mediators of training transfer. Secondary data analyses were conducted from the Staying Keen in Later Life (SKILL) study, a randomized cohort study including 126 community dwelling adults 63 to 87 years of age. In the SKILL study, participants were randomized to an active control group or cognitive speed of processing training (SOPT), a non-verbal, computerized intervention involving perceptual practice of visual tasks. Prior analyses found significant effects of training as measured by the UFOV and Timed Instrumental Activities of Daily Living (TIADL) Tests. Results from the present analyses indicate that speed of processing for a divided attention task significantly mediated the effect of SOPT on everyday performance (e.g., TIADL) in a multiple mediation model accounting for 91% of the variance. These findings suggest that everyday functional improvements found from SOPT are directly attributable to improved UFOV performance, speed of processing for divided attention in particular. Targeting divided attention in cognitive interventions may be important to positively affect everyday functioning among older adults.

Keywords

cognitive intervention; cognitive training; mediational analyses

The quality of life of older adults is negatively impacted by cognitive impairments. Although several approaches for improving cognitive functioning in older adults are available, few have actually transferred beyond the skills practiced in training (Noack, Lovden, Schmiedek, & Lindenberger, 2009), especially to everyday functional performance. Speed of processing training (SOPT) is one approach that has resulted in improvements in

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both cognitive and everyday functional abilities (Ball, Edwards, & McGwin, 2010; Edwards, Delahunt, & Mahncke, 2009; Edwards, Myers, et al., 2009; Edwards, Wadley, et al., 2005; Roenker, Cissell, Ball, Wadley, & Edwards, 2003). However, little is known about the mechanisms of SOPT. To this end, the present study examines mediators of SOPT transfer to everyday functioning.

Over the past 25 years, many studies have demonstrated that, among older adults without dementia, cognitive abilities may be enhanced through training (e.g., Ball et al., 2002; Kramer, Larish, & Stayer, 1995; Labouvie-Veif & Gonda, 1976; Peretz, Korczyn, Shatil, Aharonson, & Birnboim, 2011; Rasmusson, Rebok, Bylsma, & Brandt, 1999; Rebok, Rasmusson, & Brandt, 1996; Schaie, Hertzog, Willis, & Schulenberg, 1987). Typically three general approaches for maintaining or improving cognitive function with increasing age have been employed (Smith et al., 2009): 1. strategy enhancement; 2. cognitively-stimulating activity; and, 3. perceptual-cognitive, also called process-based, training (Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). The third approach, which is the focus of the present study, involves practice of exercises aimed at enhancing information processing.

Speed of Processing Training (SOPT)

SOPT is a process-based, computerized cognitive intervention that involves intensive practice of visual exercises designed to improve speed and accuracy of information processing (Ball, Edwards, & Ross, 2007; Edwards et al., 2002; Edwards, Wadley, et al., 2005; Roenker et al., 2003; Vance et al., 2007). This training program is aimed at enhancing performance on the Useful Field of View Test (UFOV[1]), a measure of processing speed for visual attention tasks which examines the speed at which one can rapidly process visual stimuli (Edwards, Vance, et al., 2005). This valid and reliable assessment has been used in prior research (e.g., Edwards, Wadley, et al., 2005) and consists of four subtests (processing speed; divided attention; selective attention; selective attention in conjunction with same/different discriminations) of increasing difficulty. Studies using SOPT have found large intervention effect sizes for UFOV performance as well as far transfer to real-world, performance-based tasks (which are not practiced in training) including driving outcomes (Ball et al., 2010; Edwards, Delahunt, et al., 2009; Edwards, Myers, et al., 2009; Roenker et al., 2003) and the Timed Instrumental Activities of Daily Living (TIADL) Test (Edwards et al., 2002; Edwards, Wadley, et al., 2005).

To our knowledge, as compared to other cognitive intervention techniques, only SOPT has been shown to enhance *performance* of IADL. Edwards et al. (2002) examined the impact of SOPT among a community-dwelling sample of 97 older adults (with no vision, UFOV, or mental status exclusion criteria). Results indicated that SOPT resulted in a 0.61 *sd* improvement on UFOV as compared to a no-contact control group, and that training transferred to improved performance on the TIADL test (Edwards et al., 2002). In a subsequent study, Edwards et al. (2005) examined the cognitive and everyday functioning among older adults (N=126) randomized to either SOPT or a social- and computer-contact control group. SOPT training effect sizes averaged 1.94 *sd* of improvement in UFOV performance relative to the controls indicating that gains were not due to social- or computer-contact (Edwards, Wadley, et al., 2005). These training gains transferred to improved TIADL performance. Given that the participants in the control condition were learning a new cognitively-stimulating activity (internet training), the mechanism of SOPT gains is not likely to be merely cognitive stimulation.

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

Dual-Task and Task Switching Training

Other process-based cognitive interventions, task-switching training and dual-task training, have also resulted in near transfer to untrained tasks, with some evidence of far transfer (Baron & Mattila, 1989; Bherer et al., 2005, 2008; Gopher, Weil, & Bareket, 1994; Karbach & Kray, 2009; Karbach, Mang, & Kray, 2010; Kramer et al., 1995; Kramer, Larish, Weber, & Bardell, 1999; Li et al., 2010; McDowd, 1986). For example, Karbach and Kray (2009) examined the effects of task switching training, which involves perceptual practice to quickly make one of two possible judgments about visual stimuli (i.e., category or size). Results indicated that training enhanced task switching and transferred to improved performance on other measures of fluid ability including Stroop, verbal and spatial working memory, and reasoning.

Similarly, Bherer and colleagues (Bherer et al., 2005, 2008) examined dual-task training in which participants practice quickly making perceptual discriminations of visual and auditory targets that are either presented simultaneously, or with an inter-stimulus interval of 200 ms. Results indicated improvement in dual-task performance with new stimuli similar to those practiced in the training. Li and colleagues (2010) further examined the impact of this training paradigm and demonstrated far transfer of dual-task training to improved standing balance.

Kramer and colleagues trained dual-task performance of older adults by requiring participants to practice two tasks concurrently and individually (Kramer et al., 1995; Kramer et al., 1999). The training tasks involved monitoring visual displays and required tracking a moving target by moving a cursor, and making an appropriate key press corresponding to the spatial position of a particular target in an array. Two training conditions were used in which participants applied a strategy to either devote equivalent priority to the two concurrent tasks (fixed), or to vary priority between the two tasks across practice trials. Dual-task training, particularly the variable priority condition, transferred to improved performance on a task unlike those practiced in training, alphabetic arithmetic (i.e., K-3= ? answer: H). Training also transferred to a task requiring monitoring of an array of 6 gauges (in which participants were required to reset the gauge with a key press); a task that could potentially have everyday functional relevance (Kramer et al., 1999). Gopher and colleagues found that a similar dual-task training paradigm in a game-context, Space Fortress, transferred to improved flight simulator performance (Gopher et al., 1994).

Research on these techniques of cognitive training (e.g., SOPT, task switching, dual task training) has led to the assertion that process-based training techniques may be most likely to result in far transfer to tasks dissimilar to those practiced in training (Karbach et al., 2010; Lustig et al., 2009). However, the underlying mechanisms of *transfer* of these techniques are not well explored.

Mechanisms of Cognitive Training

Studies of the mechanisms of cognitive training are few, although some studies have examined how cognitive benefits are derived from training by exploring neural correlates (Berry et al., 2010; Scalf et al., 2007; Takeuchi et al., 2011). Takeuchi and colleagues (2011) used functional Magnetic Resonance Imaging (fMRI) with young adults to show that cognitive training designed to enhance processing speed reduced regional gray matter volume, which was interpreted as reflecting more efficient cognitive processing. Scalf and colleagues used fMRI to examine how practice on a functional field of view task resulted in cognitive improvements among older adults. Results indicated training-related increased activation in brain regions associated with shifting and reorienting attentional focus to relevant stimuli. Similarly, Erickson and colleagues (Erickson et al., 2007a; Erickson et al., 2007b) examined mechanisms of dual task training using fMRI. Improvements in dual task performance were associated with shifts in regions of brain activation. The authors concluded that training led to more efficient processing, perhaps due to enhanced allocation of attention. In an Event Related Potential (ERP) study, Berry et al. (2010) found that training on perceptual processing of Gabor patches (Sweep Seeker task of the InSight cognitive training program) resulted in a decrease in the amplitude of the N1 ERP component following training. The N1 is indicative of early visual motion detection and is modulated by attention. The results suggest attentional focus was more efficient following training.

Caution is advised in interpreting the results of such studies, as the effects are likely to be specific to the given training program (Takeuchi et al., 2011). To our knowledge no published studies to date have examined the mechanisms of far transfer of cognitive training.

The present analyses are designed to further examine transfer of SOPT. Specifically we sought to determine whether the IADL performance improvements can be attributed to cognitive improvements in UFOV as a result of SOPT, and, if so, whether training transfer was mediated by performance on a particular UFOV subtest. One way to explore causal pathways, or mechanisms of action, is through statistical mediation analyses. Thus, mediators of the transfer of SOPT to improved TIADL performance are explored.

Method

Participants

Participants included older adults from the Staying Keen in Later Life (SKILL) study who were recruited at either the University of Alabama at Birmingham or Western Kentucky University. Details on recruitment, the sample characteristics, and for the SKILL study overall are described elsewhere (Clay et al., 2009; Edwards, Wadley, et al., 2005; K. M. Wood et al., 2004). Participants who were eligible for and completed the training phase of the study were included in these and prior analyses (Edwards, Wadley, et al., 2005). These individuals (N=126) ranged from 63 to 87 years of age (*M*=75.64, *SD*=5.96), were mostly female in gender (63%), and Caucasian in race (83%). Their average level of education equated to “some college or vocational training after high school.”

Inclusion criteria for training were a Mini Mental State Exam (MMSE) score of 23 or better, adequate vision (far visual acuity 20/80 or better, contrast sensitivity 1.35 or better), and adequate hearing (pure tone average of 40 dB or better in at least one ear): About 11% of participants did not meet one or more of these requirements. These inclusion criteria were chosen based on prior research (for details, see Edwards, Wadley, et al., 2005) to ensure that participants could view and hear study testing and training stimuli, and to minimize the possibility of including participants with dementia. The final criterion for inclusion in training was evidence of a speed of processing deficit (UFOV subtest 3 and 4 combined score ≥800 or subtest 2 score ≥150) to allow room for improvement with training (for details, see Edwards, Wadley, et al., 2005).

Approximately 30% of the participants screened were further eligible for training based on these inclusion criteria: 86% of participants enrolled in training completed 8 of 10 training sessions. The 126 participants who completed at least 8 sessions of training (as of September 18^{th}, 2002) and were included in prior analyses of training effects (Edwards, Wadley, et al., 2005) are also examined here.

Procedure

Participants completed a screening visit to determine eligibility and a separate baseline visit to assess speed of processing, memory, executive functioning, and IADL performance. Training-eligible participants were randomly assigned to either SOPT (n=63) or a social and computer-contact control group (n=63) who underwent internet training. Participants in both conditions attended classes led by a trainer twice a week for 10 sessions over an approximately six-week period. Immediately following training, participants' cognitive and functional abilities were reassessed.

Measures

Useful Field of View Test—UFOV is a measure of processing speed for visual attention tasks, which examines the speed at which one can rapidly process visual stimuli (Edwards, Vance, et al., 2005). This valid and reliable assessment has been used in prior research (e.g., Edwards, Wadley, et al., 2005) and consists of four subtests (processing speed; divided attention; selective attention; selective attention in conjunction with same/different discriminations) that increase in difficulty. The test was completed using a 17-in touch-sensitive monitor at an approximate viewing distance of 18 to 24 in. The first subtest requires the participant to identify which of two objects (a silhouette of a car or a truck) was presented inside a fixation box. The second test includes this central identification task with a simultaneous localization task (a peripheral car presented 11 cm from the central target). The third subtest requires the same responses as subtest 2, but adds distractors (triangles) surrounding the peripheral target. The fourth subtest is similar to the third subtest with the exception that the center task is more demanding. Two targets are presented in the central fixation box (either two cars, two trucks, or one car and one truck) and the participant must indicate if the targets inside the box are the same or different while localizing the outside car among distractors.

Each subtest begins with two examples and four practice trials. Displays were presented at decreasing exposure durations to obtain a 75% performance threshold (varied by a double-staircase method). Participants view the display and then make a response (responses are not timed). Scores for each subtest represent the minimum display presentation duration needed to obtain 75% threshold performance, ranging from 16.67 to 500 ms with lower numbers indicating a better score. If the participant was unable to perform the task at the longest display speed, a score of 500 was assigned. The test re-test reliabilities of the UFOV subtests are similar, ranging between .71 and .78 (Edwards, Vance, et al., 2005). The inter-correlations between the subtests range from .15 to .56, indicating each subtest reflects somewhat differing cognitive abilities (Edwards et al., 2006).

Timed Instrumental Activities of Daily Living—The TIADL was designed to assess rapid and efficient performance of tasks beneficial to daily life (Owsley, Sloane, McGwin, & Ball, 2002). The TIADL Test involves five timed visual tasks of everyday functional abilities intended to assess the IADL domains of telephone communication, financial abilities, nutrition, shopping, and medication usage (Owsley et al., 2002). Tasks were adapted from the direct assessment of function scale (Loewenstein et al., 1989) and include: searching for a phone number in the phone book, searching for ingredients on cans of food, searching for directions on two medicine containers, and searching for two food items on a crowded pantry shelf. For each task, time to completion is measured with a digital stopwatch (to one-tenth second) and accuracy is coded. The test was scored as detailed elsewhere and included a time penalty for incorrect responses. A composite score of time and accuracy performance was calculated and used in analyses (as detailed elsewhere, Edwards, Wadley, et al., 2005; Owsley et al., 2002). Owsley and colleagues found that TIADL performance was predicted by the standard self-report measure of IADL function (the Minimum Data

Set) as well as by the Everyday Problems Test and the Observed Tasks of Daily Living test (Owsley et al., 2002). Similarly, others have demonstrated that TIADL loads on the same factor as these two well-established measures of everyday function (Gross, Rebok, Unverzagt, Willis, & Brandt, 2011). Thus, this measure has shown criterion validity in relation to other well-accepted, performance-based measures of everyday function.

Intervention

Cognitive Speed of Processing Training—SOPT is a cognitive intervention that involves perceptual practice of visual processing tasks. The training program is designed to improve UFOV performance by improving speed and accuracy of visual processing. Participants practice visual attention exercises that involve detecting, identifying, or discriminating central targets (cars or trucks). At higher levels of difficulty, a peripheral localization task is added. The peripheral task difficulty is modified by changing target location relative to the central target, adding distractors, and adjusting the conspicuity of distractors. At the highest level of difficulty, an auditory discrimination task is also added. The primary modification at all levels of task difficulty across all exercises is display speed. Task difficulty is constantly adapted by the trainer based on each participant's ongoing performance. Further details of the standard protocol of SOPT are provided elsewhere (Ball et al., 2007).

Active control condition—A condition of internet training was used as the control group to equalize participant contact with a trainer and other participants as well as computer use. Participants received an introduction to computer hardware and software and learned how to use a computer mouse. Participants were then instructed on how to set up an e-mail account and practiced sending and receiving emails. Finally, participants were introduced to the internet, taught how to access web pages, and practiced accessing various websites to complete tasks as directed. Participants across both conditions were relatively-novel computer users (as determined by a computer use questionnaire. See Edwards, Wadley, et al., 2005 for details). Prior analyses demonstrated that computer experience was equivalent among participants between the two training conditions and that computer experience did not influence training responsiveness (Edwards, Wadley, et al., 2005).

Statistical Analyses

Analyses were conducted to examine mechanisms of the previously-documented transfer of cognitive SOPT to improved everyday functional performance (Edwards, Wadley, et al., 2005). Prior analyses indicated that the SOPT and active control group conditions did not significantly differ at baseline in UFOV or TIADL performance, nor on any demographic indicators (Edwards, Wadley, et al., 2005). Edwards and colleagues further found a significant group by time interaction when comparing UFOV and TIADL performance between the training conditions across pre- to post-test.

Participants from both the SOPT and active control conditions were included in the present analyses. First, a simple mediational model of $X \rightarrow M \rightarrow Y$ (where X was training condition - SOPT or active control, M was the UFOV total score at post-test, and Y was TIADL score at post-test) explored whether the UFOV total score mediated the effects of cognitive SOPT on TIADL performance (see Figure 1). Significant mediation effects were followed with a multiple mediation model to examine if one or more particular subtests of post-test UFOV performance independently mediated the relationship between training condition and post-test TIADL performance by controlling for performance on the other subtests. Performance on each of the four UFOV subtests at post-test were simultaneously entered into this model (see Figure 2). For both models, bootstrap analysis with bias corrected confidence estimates (Dearing & Hamilton, 2006; MacKinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2004, 2008) was used in order to avoid the problems associated with the Sobel test (Baron & Kenny, 1986) when working with finite or small samples (Preacher & Hayes, 2004). The analyses and bootstrap estimates were based on 5,000 bootstrap samples (Preacher & Hayes, 2004). For the multiple mediation model, this method allowed simultaneous entry of four potential mediators into the model and tested for an overall indirect effect. This method eliminates the omitted mediator problem by testing each individual mediator's independent effect while controlling for all other variables in the model (Judd & Kenny, 1981; Preacher & Hayes, 2008). The indirect effect of UFOV performance on TIADL performance was calculated by multiplying the point estimate *a* (direct effect of training condition on UFOV) x point estimate *b* (direct effect of UFOV on TIADL) paths, which is denoted by *ab* (Preacher & Hayes, 2004, see Figures 1 and 2). The *ab* point estimates represent the expected change in Y (TIADL) that accompanies a one unit change in X (training) resulting from the direct effect of X on M (UFOV), which then affects Y. The total indirect effect of the four subtests on Y in the multiple mediation model is the sum the individual indirect effects. Finally, the proportion of the total effect that was mediated was calculated using the formula $[1 - c'/c]$ (Kenny, Kashy, & Bolger, 1998), in which c' = direct effect of training and c = total effect of training (direct and indirect effects)[2].

Results

First, the UFOV total score was examined as a mediator in a simple mediation model. As can be seen in Figure 1, the *total* effect of training condition on TIADL performance at post-test was significant, $c = 0.23$, $t(125) = 1.94$, $p = .05$. In addition, the model's *a* and *b* paths were significant and in the expected direction (see Figure 1), *ts*(125) = 8.34 and 2.27, *ps* < .05. The *indirect* effect of post-test UFOV performance significantly mediated the training effect on post-test TIADL performance, with point estimates (*ab*) of 0.20 and CIs 95% of 0.02 to 0.41. The estimated proportion of the training effect that was mediated was 87%. The *direct* effect of SOPT on TIADL, after adjusting for the mediator, was not significant (see Figure 1), $c' = 0.03$, $t(125) = 0.22$, $p = .83$, suggesting that UFOV performance completely mediated the effect of training on TIADL performance.

To examine whether a particular UFOV subtest mediated the effect of training on TIADL performance, all four subtests were examined as mediators in one multiple mediation model (Figure 2). The total *indirect* effect of the four UFOV subtests was significant, point estimate (*ab* path calculated by summing the four specific indirect effects) = 0.25, CI 95% of 0.05 to 0.58. A large proportion of the training effect was mediated with an estimate of 91%, and the *direct* effect of training on TIADL performance was not significant, $c' = -0.02$, $t(125) = -0.11$, $p = .91$. These results suggest complete mediation given that the direct effect of training on TIADL performance was no longer significant once adjusted for the mediators. An examination of the specific indirect effects (*ab*) revealed that only subtest 2 (speed of processing for divided attention) of the UFOV significantly mediated the effect of SOPT on TIADL performance, point estimate (*ab*) of 0.26 and CI 95% of 0.07 to 0.63. The indirect effects of UFOV performance for subtests 1, 3 and 4 did not significantly mediate the training effect on TIADL performance, with point estimates (*ab*) of 0.02, −0.07, and 0.04, 95% CIs of −0.03 to 0.07, −0.34 to 0.07, and −0.04 to 0.14, respectively. Unlike UFOV subtest 2, both UFOV subtests 3 and 4 contain an inhibitory component that may not be as relevant as divided attention to SOPT transfer to improved everyday functioning. Therefore, it appears that the effect of cognitive SOPT on TIADL performance is due to post-training performance on UFOV subtest 2 (speed of processing for a divided attention task).

[2]We chose not to use the formula *ab/c* because this formula can be unstable and may be greater than 1, especially when c is small (Kenny et al., 1998).

Discussion

Very few cognitive training programs for older adults have demonstrated far transfer to improved everyday functional performance. Although SOPT has transferred to everyday functional improvements across multiple randomized trials (Ball et al., 2010; Edwards, Myers, et al., 2009; Edwards et al., 2002; Edwards, Wadley, et al., 2005; Roenker et al., 2003), mediators of such gains have not previously been examined. These analyses are the first to begin to examine potential mechanisms of far transfer of cognitive SOPT by using mediation analyses. Mediation analyses allow the examination of causal pathways and mechanisms of action in order to determine how an intervention is effective. These analyses examined whether the transfer of SOPT to improved TIADL performance was directly attributable to post-training UFOV performance (the primary outcome that SOPT is designed to improve). Specifically, we examined UFOV total score as well as performance on individual subtests alone. UFOV performance was found to significantly mediate the influence of training on TIADL performance. More specifically, post-training performance on the divided attention subtest of the UFOV was found to be solely responsible for the mediation of training transfer. Given that the reliabilities of the UFOV subtests are relatively equivalent, this result cannot merely be attributed to better reliability of subtest 2.

However, these results may, in part, be due to greater sensitivity of UFOV subtest 2 as compared to the other subtests. Because of ceiling effects, performance changes from training on UFOV subtest 1, processing speed, are minimal. This may explain the lack of significant mediation by subtest 1. In addition, previous results show that this task reflects basic visual processing without a distributed attention component, and is thus less likely to predict everyday functional outcomes (J. M. Wood, Dique, & Troutbeck, 1993). Neither subtest 3 nor subtest 4 independently accounted for transfer of training to improved TIADL performance. Floor effects on UFOV subtest 4 may limit training gains and explain lack of mediation for this subtest. Unlike UFOV subtest 2, both UFOV subtests 3 and 4 contain an inhibitory component that may not be as relevant as divided attention to transfer to everyday functioning among older adults. The present results indicate that only the divided attention subtest of UFOV independently mediated transfer of training to improved everyday function. Similarly, Verhaeghen (2011) found that once divided attention difficulties are accounted for, there are no age-related deficits in selective attention. Overall, UFOV subtest 2, speed of divided attention without distraction, may be most sensitive to age-related cognitive and everyday functional impairments.

Age-related impairments in cognitive and everyday function can be attributed, in part, to deficits in divided attention. Divided attention costs in tasks involving higher level cognitive abilities such as visual search and memory encoding/retrieval have been demonstrated in older adults as compared to younger counterparts (e.g., Anderson, Craik, & Naveh-Benjamin, 1998; Wilson et al., 2010). Divided attention impairments are also linked to problems in driving performance and crash risk (Plude & Hoyer, 1986; J. M. Wood et al., 1993). Interestingly, prior study has documented that performance on the UFOV divided attention subtest in particular is most predictive of driving outcomes (Ball et al., 2006). These findings as well as the results of the present analyses indicate that improving the speed and accuracy of visual information processing when attentional resources are divided may be important for enhancing everyday functional performance.

Other training studies have also shown the value of enhancing divided attention through dual-task training (e.g., Kramer et al., 1995). Interestingly these training paradigms have also resulted in far transfer of training to tasks relevant to everyday functioning (Gopher et al., 1994; Li et al., 2010); a finding that is overall rare in cognitive intervention research. Such findings have led some to conclude that process-based training techniques may be most likely to result in far transfer to tasks dissimilar to those practiced in training (Karbach et al., 2010; Lustig et al., 2009). The dual task training paradigms are quite different from SOPT. Of interest would be comparing these differing training techniques using common outcome measures to further attempt to identify underlying mechanisms of effective cognitive interventions. To date, evidence from these prior studies and the present results indicate that enhancing divided attention may be key to obtaining transfer of cognitive training to everyday performance.

There are limitations to the present study. It is important to acknowledge that the inclusion criteria requiring baseline UFOV difficulties limited the profile of participants included in training in the SKILL study. This may be considered a limitation of the present study with regard to generalization of the findings. However, prior studies in differing samples, which did not exclude participants based on UFOV performance, similarly found SOPT training gains in UFOV performance, and transfer of training to Timed IADL improvements (Ball et al., 2002; Edwards et al., 2002). These studies lessen this potential concern.

Another limitation of these analyses is that the only measures that reflected significant training gains from SOPT in the SKILL study were UFOV and TIADL; it is not known what other indices of cognitive speed of processing and visual attention may be impacted by SOPT. The UFOV subtest 2 is a complex task that taps sensory function, cognitive speed of processing, and attention (Lunsman et al., 2008; Owsley & Sloane, 1987). Prior study has *not* found transfer of SOPT to cognitive indices of executive control (e.g., Stroop, Trail Making Test, task switching), indicating that speed of processing may play a larger role in training-derived gains than attentional control (Edwards et al., 2002; Edwards, Wadley, et al., 2005). However, the relationships between cognitive speed of processing and executive function, such as attentional control, are complex and reflect overlapping constructs (Verhaeghen, 2011). Prior research exploring neural correlates of process-based cognitive training have demonstrated that training-derived gains are likely the result of improved processing efficiency and enhanced attentional resource allocation. Interestingly, the UFOV divided attention subtest draws on both of these abilities. Without further study including multiple markers of visual sensory function, attention, speed of processing and executive function as training outcomes, the exact mechanisms of SOPT transfer remain unclear. Studies specifically designed to examine mechanisms of SOPT by mediation analyses should ideally examine mediators at a midpoint of intervention (Kraemer, Wilson, Fairburn, & Agras, 2002). Nevertheless, these analyses provide a first step in this direction and will guide further research, which should examine other indicators of divided attention in relation to SOPT to confirm these findings.

Overall, these results indicate that cognitive training gains in the divided attention subtest of the UFOV completely mediated the transfer of SOPT to improved everyday functional performance. Thus, SOPT results in improved speed of divided attention, which results in improved performance on TIADL. The TIADL improvements found from SOPT can be directly attributed to improved UFOV performance, divided attention in particular. Overall this study and other research findings indicate that improving divided attention may be important to positively affect everyday functioning of older adults. It may be that cognitive interventions targeting divided attention will be most effective.

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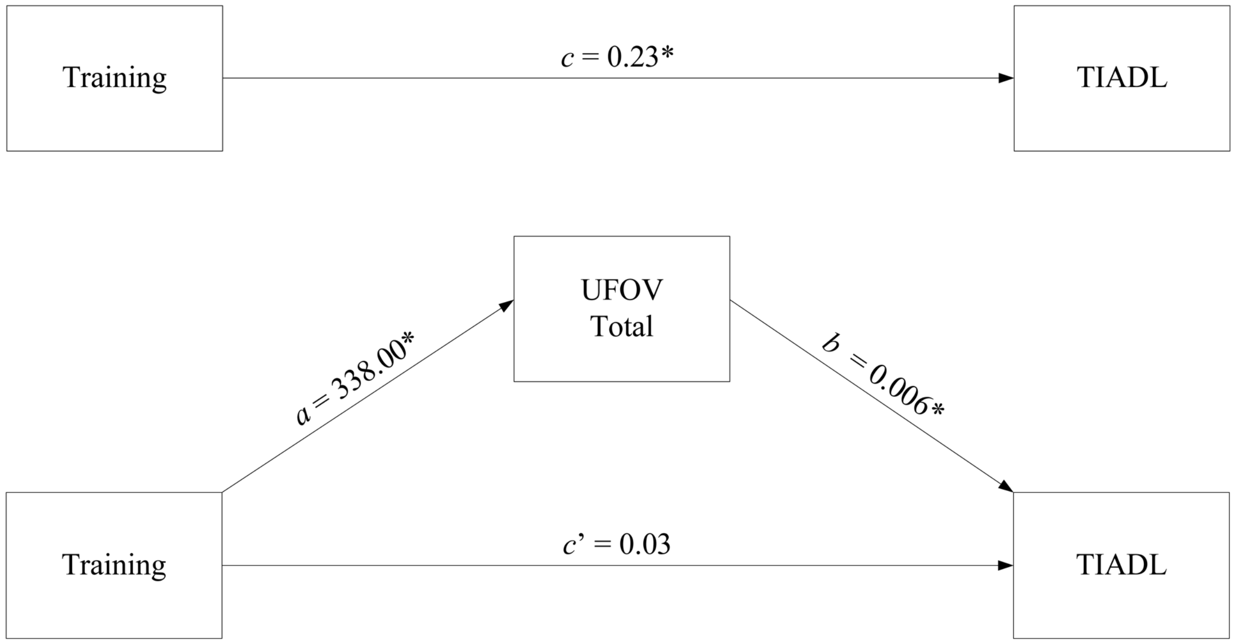

Figure 1.

Simple Mediation Model with Useful Field of View Test (UFOV) Total Score as Mediator. The simple mediation model of $X \rightarrow M \rightarrow Y$ (where X is training condition, M is UFOV total score at post-test, and Y is TIADL at post-test). The bootstrapping method with bias-corrected confidence estimates (based on 5,000 bootstrap samples) was used to test the mediation hypothesis (Preacher & Hayes, 2004). The indirect effect of the mediator (*ab*) is presented in text and was calculated by multiplying $a \times b$ paths. An asterisk indicates that the bootstrap estimate is significant at the 0.05 alpha level.

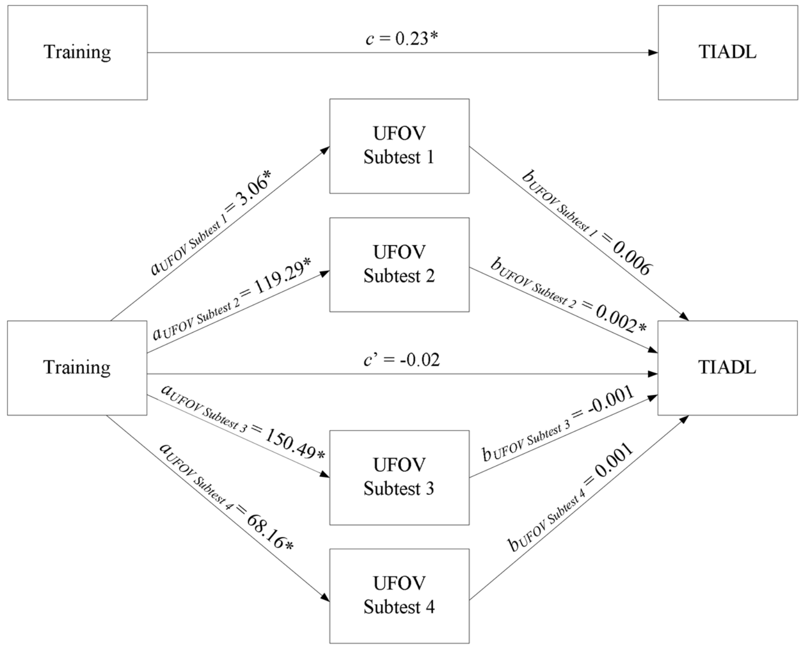

Figure 2.

The multiple mediation model of $X \rightarrow M \rightarrow Y$ (where X is training condition, M is the four Useful Field of View Test (UFOV) subtests scores at post-test, and Y is TIADL at post-test). The bootstrapping method with bias-corrected confidence estimates (based on 5,000 bootstrap samples) was used to test the multiple mediation model (Preacher & Hayes, 2004). The indirect effects of the specific mediators (*ab*) are presented in text and were calculated by multiplying $a \times b$ paths. The total indirect effect of the four UFOV subtests is also presented in text and is the sum of the four specific effects. An asterisk indicates that the bootstrap estimate is significant at the 0.05 alpha level.