



Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review article

Systematic review and meta-analyses of useful field of view cognitive training



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ARTICLE INFO

Keywords:

Cognitive training
Cognitive intervention
Driver training
Perceptual learning
Brain training

ABSTRACT

Systematic review and meta-analyses were conducted of Useful Field of View (UFOV) training, which was evaluated by Institute of Medicine criteria. Forty-four studies of UFOV training from 17 randomized trials conducted among adults were identified in systematic review. Results addressing the Institute of Medicine criteria indicated that: (a) UFOV training enhanced neural outcomes, speed of processing, and attention. (b) UFOV training effects were equivalent when compared to active- or no-contact control conditions. (c) UFOV training showed far transfer to everyday function. (d) Improvements on the trained skills endured across ten years. (e) Half of the clinical trials identified were conducted by researchers without financial interests in UFOV training. Results indicated that UFOV training effects were larger for adaptive- than non-adaptive training techniques, and in community-based as compared to clinical samples. UFOV training did not transfer to other neuropsychological outcomes, but positively enhanced well-being, health, and quality of life longitudinally. Criticisms of cognitive training are addressed. UFOV training should be implemented among older adults to improve real-world functional outcomes and well-being.

1. Introduction

As interest in and evidence for the efficacy of cognitive training is growing, so is controversy surrounding this field (Hambrick, 2014; Lampit et al., 2015; Merzenich et al., 2015; Ratner and Atkinson, 2015; Simons et al., 2016; Stanford Center on Longevity and Berlin Max Planck Institute for Human Development, 2014). Unfortunately, the majority of published reviews of cognitive training research equate approaches and types, despite the fact that different cognitive training approaches have unique effects. Such reviews ‘muddy the waters’ and contribute to the ongoing controversy. A recent meta-analysis concluded that different types of cognitive interventions produce varying magnitudes of effect sizes as well as patterns of transfer (Kelly et al., 2014). Thus, some cognitive training may transfer to improved real-world functioning and some may not. This is important as one of the primary criticisms of cognitive training and reviews thereof is a lack of training transfer beyond the abilities targeted by the intervention (Noack et al., 2009; Rabipour and Raz, 2012; Reijnders et al., 2013). To advance this field, systematic reviews and meta-analyses must focus on

evaluating the evidence for specific cognitive interventions given that effects vary by approach. To this end, we quantify the effects of one promising and well-studied cognitive intervention, Useful Field of View (UFOV) training.

1.1. Process-based cognitive training

UFOV training, which is also known as cognitive speed of processing training, is a process-based perceptual/cognitive training technique. Process-based, computerized, cognitive training involves perceptual practice exercises targeting fundamental cognitive abilities such as attention or speed of processing (Lustig et al., 2009). This approach is grounded in the information degradation theory (Humes et al., 2013; Mahncke et al., 2006; Schneider and Pichora-Fuller, 2000; Sekuler and Blake, 1987), which posits that age-related changes in the brain cause perceptual processing errors that negatively affect cognition. According to this perspective, targeting perceptual processing may be the best way to enhance older adults’ cognition. Interestingly, process-based cognitive training tends to produce larger effect sizes and may be more likely

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<https://doi.org/10.1016/j.neubiorev.2017.11.004>

Received 9 March 2017; Received in revised form 4 November 2017; Accepted 6 November 2017

Available online 22 November 2017

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to transfer than other techniques (Kelly et al., 2014; Lampit et al., 2015). Results from the single largest randomized trial of cognitive training among older adults, ACTIVE, support this assertion (Ball et al., 2002; Jobe et al., 2001). The training effect sizes on the targeted proximal outcomes (i.e., the ability that was exercised in training) were 3–5 times larger for process-based UFOV training than other cognitive training techniques (Ball et al., 2002).

1.2. Adaptive training

One reason that process-based cognitive training may be more effective is that this training technique typically includes exercises that are adaptive in difficulty. The model of adult plasticity indicates that cognitive training programs that are adaptive in difficulty will be most effective (Lovden et al., 2010). Adaptive training is a technique in which the level of difficulty of the cognitive training exercises is targeted to the ongoing performance of the user. As accuracy of performance is achieved at a specified level (e.g., 75%), exercise difficulty is increased incrementally as performance improves. Increasing evidence demonstrates that when adaptive training is used, transfer, including far transfer to everyday function, is observed (Kelly et al., 2014).

1.3. Useful field of view training

UFOV training is a particularly promising process-based approach that has been studied among older adults for thirty years (Ball et al., 1988; Sekuler and Ball, 1986). A systematic review of computerized cognitive training (which included mostly process-based techniques) showed that UFOV training produced the largest gains relative to controls (Kueider et al., 2012). A recent qualitative critique of cognitive training studies overall concluded that there is “little compelling evidence for transfer of training” (p. 138), but the most robust benefits may be derived from UFOV training, which was noted as “one exception” (Simons et al., 2016). The ACTIVE study results not only showed that UFOV training demonstrated the largest cognitive improvements on the targeted proximal outcome (Ball et al., 2002), but further analyses indicated that UFOV training resulted in lasting proximal improvements with significant effects still evident 10 years later (Rebok et al., 2014; Willis et al., 2006). Unlike other cognitive intervention approaches, UFOV training has shown transfer to improved functional performance on instrumental activities of daily living (IADL) among older adults (Edwards et al., 2013b, 2002, 2005b; Lin et al., 2016; Vance et al., 2012; Willis et al., 2006). IADL are abilities (i.e., managing finances, shopping, preparing meals) vital to older adults’ maintained independence (Lawton and Powell, 1969). Research has also demonstrated that UFOV training results in safer and prolonged driving mobility among older adults (Ball et al., 2010; Edwards et al., 2009a, 2009b; Roenker et al., 2003). In addition to the benefits on functional outcomes, UFOV training results in maintained health and well-being across several indicators (Wolinsky et al., 2009a, 2010, 2009c, 2006a, 2006b, 2009d). Most recently, and perhaps of the utmost importance, UFOV training may longitudinally delay the onset of dementia (Edwards et al., in press). Nevertheless, critics assert that the effects of cognitive training in general are not supported by theory, may be attributable to expectations and beliefs, are not enduring and do not transfer to real-world measures, declare that results are biased because multiple statistical corrections were not applied, and question the value of observed transfer of training to real-world outcomes (Simons et al., 2016).

1.4. Purpose of current study

The goal of this systematic review and meta-analysis was to evaluate the effects of one specific process-based cognitive intervention, UFOV training (a.k.a., speed of processing training). We first quantified the effects of training on the proximal outcome of UFOV performance

across studies. We compared adaptive and non-adaptive techniques as well as effects among community-based and clinical samples. Following the 2015 Institute of Medicine recommendations from the “Report on Cognitive Aging” (Institute of Medicine, 2015), we further aimed to evaluate UFOV training using the following criteria:

1. Has the training program been evaluated relative to an active control group whose members have the same expectations of cognitive benefits as do members of the experimental group?
2. Has the training program demonstrated transfer of training to other laboratory tasks that measure the same cognitive construct as the training task?
3. Has the training program demonstrated transfer of training to relevant real-world tasks?
4. How long are the trained skills retained?
5. Have the purported benefits of the training program been replicated by research groups other than those selling the product?

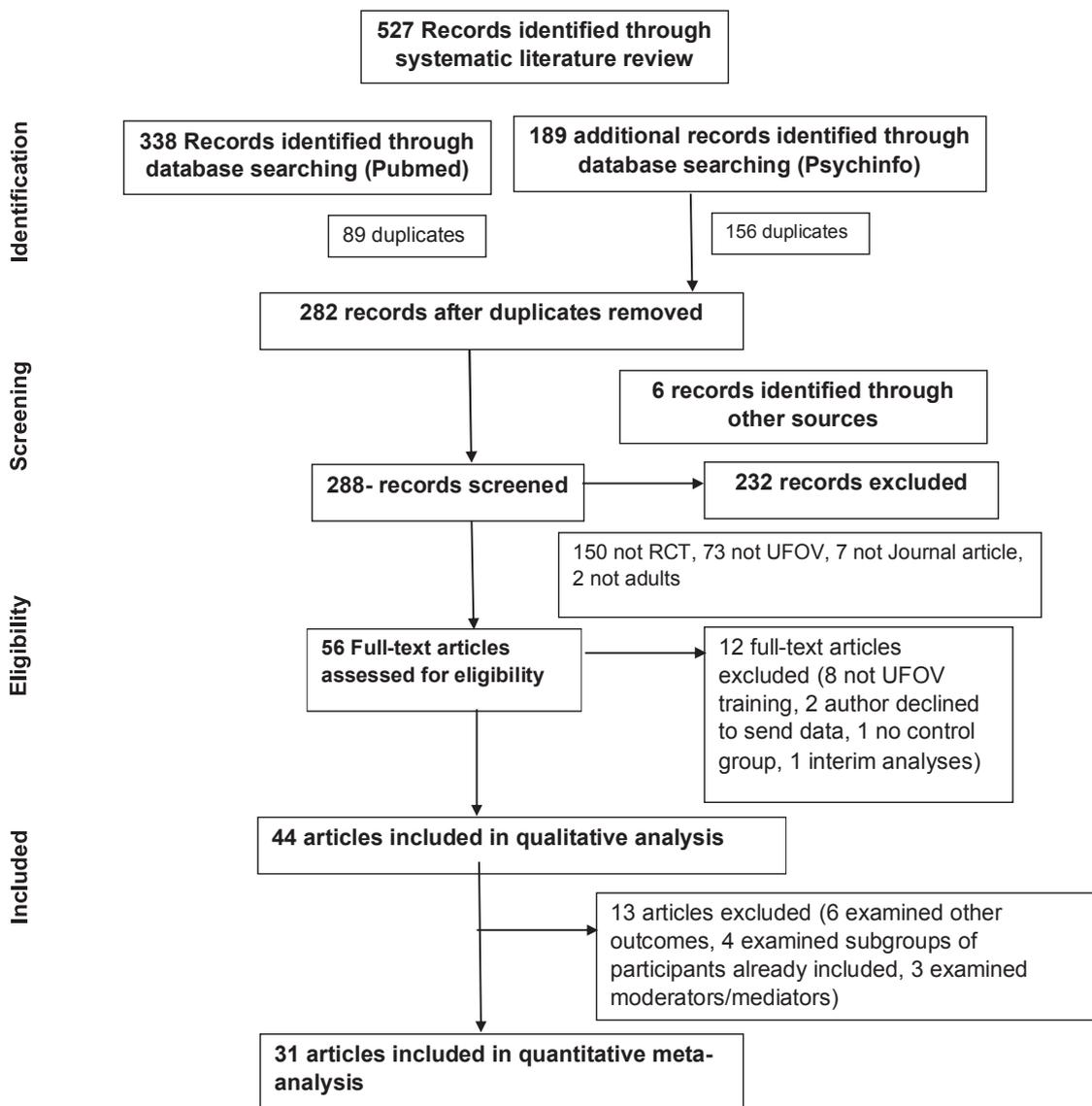
We quantified the effects of the training program on outcomes of particular importance to older adults such as well-being and quality of life.

2. Method

2.1. Identification of relevant studies

This systematic literature review and meta-analysis was prospectively registered with PROSPERO (2016 CRD42016027424). The goal was to identify empirical studies that examined the effects of UFOV training (a.k.a., cognitive speed of processing training) in a randomized clinical trial. Our *a priori* registered inclusion criteria specified that only results published in peer-reviewed journal articles in the English language were selected for inclusion. However, to be more inclusive and address potential publication bias, we later reviewed the abstracts of articles obtained from the search that were not published in English, and none were trials of UFOV training. Studies among adults were included and those with children as participants were excluded.

Between September 21 and November 30, 2015, systematic literature searches were performed in PubMed and PsychINFO databases using the following search terms: Useful Field of View & training, “speed of processing training”, UFOV & training, or “speed of processing” & training. The number of articles identified and selected for inclusion in analyses are detailed in Fig. 1 per PRISMA guidelines. The searches yielded a total of 282 records from both databases after removing duplicates. Six additional publications (including three additional randomized clinical trials) on UFOV training were identified primarily through citation alerts (Lin et al., 2016; Ross et al., 2015; Ross et al., 2017; Smith-Ray et al., 2014a, 2014b; Unverzagt et al., 2012). The resulting 288 articles were initially screened for inclusion by two independent raters (blinded for review). Of these, 232 articles were excluded: 150 were not randomized clinical trials, 73 did not use UFOV training, seven were not peer-reviewed journal articles, and two included children as participants. Fifty-six full-text studies were examined for inclusion in analyses. After full-text review by two independent raters (blinded for review) a total of 44 articles from 17 different clinical trials met the inclusion criteria. (Three discrepancies between reviewers one and two were resolved by reviewer three with 100% agreement between reviewers two and three). Thirty-one of these publications were from 15 different randomized clinical trials and were included in quantitative analyses. Please see Fig. 1 for details and Table 1 for a list of trials and publications. The PEDro scale (de Morton, 2009) was used to rate the quality of studies on a 10-point scale by two independent raters (doctoral students blinded for review) with inter-rater reliability of 0.78. The average across all ratings of the studies was 6.22 ($SD = 1.45$). Between November 8 to 16, 2016 a search of the gray literature using the same terms as detailed above was performed by a



Note. A subsequent gray literature search identified four additional articles

Fig. 1. Records identified through systematic literature review.

qualified librarian to identify any unpublished trials: four additional studies were identified and are described in qualitative analyses.

2.2. Participants

The vast majority of the studies recruited community-dwelling older adults (typically 60 years and older). One study (Wolinsky et al., 2013) specifically also included middle aged adults (50–64 years of age), and one included only those 19–31 years of age (Burge et al., 2013). Five studies were conducted among clinical populations (Akinwuntan et al., 2010; Edwards et al., 2013a; Lin et al., 2016; Vance et al., 2012; Von Ah et al., 2012).

2.3. Procedure

The independent variable of interest was computerized UFOV training. This included both adaptive and non-adaptive forms of the traditional training targeted at improving UFOV, which involved 18 different visual tasks across 10 levels of display speeds requiring identification and localization of white targets (cars/trucks) with and

without distractors (visual- triangles or auditory- tone sweeps). Also included were updated and expanded versions of UFOV training such as InSight (Edwards et al., 2013a, 2015; Lin et al., 2016), which included five different visual exercises, one of which is a direct translation of the original UFOV training exercises, Road Tour (Wolinsky et al., 2013). This exercise is currently marketed by Posit Science as BrainHQ Double Decision. UFOV training typically involves ten 1-h sessions, although some studies have included more hours (e.g., up to 30) or additional booster training after the initial intervention period. The dependent measures included in analyses are described in Table 2.

2.3.1. Useful field of view test

To establish the effect size of training on the proximal outcome of UFOV performance, compare adaptive and non-adaptive techniques, examine community-based and diseased samples, and assess training effects relative to an active control group, we quantified the effects of training across studies on UFOV test performance, which is summarized as a total score in ms of three subtests (Edwards et al., 2005a). Although some field studies have examined the predictive ability of UFOV subtest 2 alone (Ball et al., 2006), and the ACTIVE study included a fourth

Table 1
Publications of Randomized Trials of Useful Field of View Training.

Trial	Author and Year	Publication Title
1 ACTIVE	Ball et al. (2002)	Effects of cognitive training interventions with older adults: A randomized controlled trial
	Willis et al. (2006)	Long-term effects of cognitive training on everyday functional outcomes in older adults.
	Wolinsky et al. (2006a)	The ACTIVE cognitive training trial and health related quality of life: Protection that lasts for 5 years.
	Wolinsky et al. (2006b)	The effects of the ACTIVE cognitive training trial on clinically relevant declines in health-related quality of life
	Unverzagt et al. (2007)	+ Effect of memory impairment on training outcomes in ACTIVE.
	Wolinsky et al. (2009a)	+ The ACTIVE cognitive training trial and predicted medical expenditures.
	Wolinsky et al. (2009b)	The ACTIVE cognitive training interventions and the onset of and recovery from suspected clinical depression.
	Wolinsky et al. (2009c)	The effect of speed-of-processing training on depressive symptoms in ACTIVE.
	Wolinsky et al. (2009d)	Does cognitive training improve internal locus of control among older adults?
	Ball et al. (2010)	Cognitive training decreases motor vehicle collision involvement of older drivers.
	Wolinsky et al. (2010)	Speed of processing training protects self-rated health in older adults: enduring effects observed in the multi-site ACTIVE randomized controlled trial.
	Unverzagt et al. (2012)	+ ACTIVE cognitive training and rates of incident dementia.
	Valdes et al. (2012)	+ The effects of cognitive speed of processing training among older adults with psychometrically- defined mild cognitive impairment.
	Ball et al. (2013)	Speed of processing training in the ACTIVE study: How much is needed and who benefits?
Ellis et al. (2014)	+ Effects of cognitive speed of processing training among older adults with heart failure.	
Rebok et al. (2014)	Ten-year effects of the advanced cognitive training for independent and vital elderly cognitive training trial on cognition and everyday functioning in older adults.	
Ross et al. (2015)	The transfer of cognitive speed of processing training to older adults' driving mobility across 5 years.	
Ross et al. (2017)	The impact of three cognitive training programs on driving cessation across 10 years: A randomized controlled trial	
2	Edwards et al. (2002)	Transfer of a speed of processing intervention to near and far cognitive functions.
3	Roemaker et al. (2003)	Speed-of-processing and driving simulator training result in improved driving performance.
4 SKILL	Edwards et al. (2005b)	The impact of speed of processing training on cognitive and everyday performance.
	Edwards et al. (2009b)	The longitudinal impact of cognitive speed of processing training on driving mobility.
1 & 4 ACTIVE/SKILL	Edwards et al. (2013b)	+ An examination of mediators of the transfer of cognitive speed of processing training to everyday functional performance.
	Elliott et al. (2014)	+ Cognitive speed of processing training in older adults with visual impairments.
5	Edwards et al. (2009a)	Cognitive speed of processing training delays driving cessation.
6	Sharpe et al. (2014)	+ Does self-efficacy affect responsiveness to cognitive speed of processing training?
7	Wadley et al. (2006)	Development and evaluation of home-based speed-of-processing training for older adults.
6 Accelerate	Vance et al. (2007)	The Accelerate study: The longitudinal effect of speed of processing training on cognitive performance of older adults.
7	Akinwuntan et al. (2010)	Retraining moderately impaired stroke survivors in driving-related visual attention skills.
8	Von Ah et al. (2012)	Advanced cognitive training for breast cancer survivors: a randomized controlled trial.
9	Vance et al. (2012)	Speed of processing training with middle-age and older adults with HIV: A pilot study.
10	Kaur et al. (2014)	+ Predictors of improvement following speed of processing training in middle-aged and older adults with HIV: A pilot study.
	Belchior et al. (2013)	Video game training to improve selective visual attention in older adults.
11	Belchior et al. (2012)	+ Older adults' engagement with a video game training program
12	Burge et al. (2013)	Processing speed training increases the efficiency of attentional resource allocation in young adults
13	Edwards et al. (2013a)	Randomized trial of cognitive speed of processing training in Parkinson disease.
14 IHAMS	Edwards et al. (2015)	The efficacy of InSight cognitive training to improve useful field of view performance: A brief report.
	O'Brien et al. (2013)	Cognitive training an selective attention in the aging brain: An electrophysiological study.
15	Wolinsky et al. (2013)	A randomized controlled trial of cognitive training using a visual speed of processing intervention in middle aged and older adults.
	Wolinsky et al. (2015)	The effect of cognitive speed of processing training on the development of additional IADL difficulties and the reduction of depressive symptoms: Results from the IHAMS randomized controlled trial.
16	Wolinsky et al. (2016)	+ Effects of cognitive speed of processing training on a composite neuropsychological outcome: Results at one-year from the IHAMS randomized controlled trial.
17	Smith-Ray et al. (2014a)	+ Impact of cognitive training on balance and gait in older adults.
18	Smith-Ray et al. (2014b)	+ A randomized trial to measure the impact of a community-based cognitive training intervention on balance and gait in cognitively intact black older adults.
19	Lin et al. (2016)	Cognitive and neural effects of vision-based speed-of-processing training in older adults with amnesic mild cognitive impairment: A pilot study.

Note. + denotes articles included in qualitative analyses only. Gray literature search identified four additional articles not included in quantitative analyses: American Automobile Association, 2016; Denning, 2013; Johnston et al., 2015; Sorenson, 2012.

UFOV subtest (which was created for the study), the standard UFOV metric is to summarize performance across the three subtests. As this is standard procedure, and UFOV training exercises are aimed at improving performance across all of the subtests, we included total scores as the outcome of interest. Effects were averaged across time. We averaged effects across time to use all available data points and to be conservative in our estimates of effect size, given that training gains are likely to subside over time. Results are thus reflective of the real-world benefits of training. Proximal effect sizes were quantified across 11 studies that included UFOV as an outcome (Akinwuntan et al., 2010; Ball et al., 2002; Belchior et al., 2013; Edwards et al., 2002, 2005b; Lin et al., 2016; Roemaker et al., 2003; Vance et al., 2007; Vance et al., 2012; Von Ah et al., 2012; Wadley et al., 2006; Wolinsky et al., 2013). Effects from studies examining UFOV training relative to active-control conditions (Akinwuntan et al., 2010; Belchior et al., 2013; Edwards et al.,

2005b; Lin et al., 2016; Roemaker et al., 2003; Vance et al., 2007; Wadley et al., 2006; Wolinsky et al., 2013) were compared to those using a no-contact control group (Ball et al., 2002; Edwards et al., 2013b, 2015, 2002; Rebok et al., 2014; Vance et al., 2007; Von Ah et al., 2012; Willis et al., 2006). Effects of adaptive training (Belchior et al., 2013; Edwards et al., 2013b; Roemaker et al., 2003; Vance et al., 2007; Wolinsky et al., 2013) were examined relative to effects of partially- or non-adaptive training across samples of healthy older adults (Ball et al., 2002; Edwards et al., 2002; Rebok et al., 2014; Wadley et al., 2006; Willis et al., 2006). Studies of only adults with diseases including HIV, Parkinson's, breast cancer, or stroke (Akinwuntan et al., 2010; Edwards et al., 2013a; Lin et al., 2016; Vance et al., 2012; Von Ah et al., 2012) were compared to those including community-based samples of relatively-healthy older adults (Ball et al., 2002; Belchior et al., 2013; Edwards et al., 2015, 2005b, 2002; Roemaker et al., 2003; Wadley et al.,

Table 2
Outcome Measures included in Quantitative Analyses of Useful Field of View Training Effects.

Domain	Measure	Description of Measure; Psychometric Properties	References	
Proximal	Useful Field of View Test (UFOV)	Speed of processing for visual attention tasks measuring display speed threshold in ms; test-retest reliability = 0.80	Edwards et al. (2005a)	
Speed of Processing	Everyday Speed	A composite measure of the Road Sign Test, a complex reaction time measure, and Timed IADL (i.e., a timed measure of instrumental activities of daily living performance); test-retest reliability range = 0.45–0.64	Ball et al. (2002)	
	Finding As	Processing speed to identify the letter A among other letters; test-retest reliability = 0.86	Ekstrom et al. (1976),	
	Trails A	Complex visual scanning and psychomotor speed to connect circles with numbers sequentially; test-retest reliability range = 0.53–0.64	Strauss et al. (2006);	
	Symbol Digit Modalities Test	Substitution task based on how many of 110 possible digit-symbol pairs are correctly completed in 90 s; test-retest reliability = 0.89–0.97	Morrow et al. (2010)	
	Digit Symbol Substitution	Psychomotor speed to complete as many substitutions as possible in 90 s using a key that pairs digits 1 through 9 with symbols; test-retest reliability range = 0.82–0.88	Lezak (1995)	
	Letter/Pattern Comparison	Processing speed to compare sets of pattern/letters to exemplar; letter comparison test-retest reliability = 0.77, Pattern comparison test-retest reliability = 0.87	Salthouse and Meinz (1995)	
	Identical Pictures	Processing speed to identify a target picture among five pictures; test-retest reliability range = 0.81–0.87	Ekstrom et al. (1976)	
	Attention	Digit Vigilance	Sustained attention, psychomotor speed, alertness, and vigilance to cross out a target number (6 or 9) that appears randomly among an array of other numbers; test-retest reliability = 0.91	Lewis and Rennick (1979); Lezak (1995)
Starry Night Test		Visual sensory function and spatial attention task to indicate when a centrally or peripherally located star blinks; test-retest reliability = 0.77	Deouell et al. (2005); Vance et al. (2007)	
Memory	Squires Subjective Memory Questionnaire	18-item questionnaire on perceived memory function; test-retest reliability = 0.89		
	Auditory Verbal Learning Test (AVLT)	Episodic verbal learning and memory test to learn and recall a list of 15 nouns over five trials (List A), recall an interference list (List B) and then recall List A. After 20-min delay, List A is recalled; test-retest reliability range = 0.61–0.86	Lezak (1995); Mitrushina et al. (2005); Rey (1941)	
	Benton Visual Retention Test	Visual memory and visuoconstructive abilities to draw a design from memory over three trials; Interrater reliability range = 0.96–0.97	Lezak (1995); Sivan (1992)	
	Rey-O Complex Figure Test	Visual memory, perceptual organization, and planning to copy a figure and recall the figure from memory; test-retest reliability range = 0.60–0.76	Lezak (1995)	
	Digit Span (Wechsler Memory Scale-III)	Short-term memory to recall a series of orally-presented numbers (Forward Condition). Backward condition requires recall of the numbers in the reverse order; test-retest reliability = 0.70	Lezak (1995)	
	Spatial Span	Visuospatial memory requiring recalling and repeating a sequence of blocks; test-retest reliability range = 0.40–0.78	Lezak (1995)	
	Executive Functioning	Controlled Oral Word Association Test	Phonemic verbal fluency based on the number of unique words beginning with the letter C (or F or L) generated during 60 s; test-retest reliability = 0.74	Benton et al. (1994); Ruff et al. (1996)
		Phonemic and category fluency	Verbal fluency to list as many words that begin with a particular letter or belong in a certain category; Cronbach's alpha range = 0.78–0.88	Kramer (2011)
Paced Auditory Serial Addition Test (PASAT)		Working memory to listen to lists of numbers presented at a rate of 2.0 or 2.4 s, add the last two numbers presented, and answer aloud; Interobserver reliability = 0.79	Deouell et al. (2005); Vance et al. (2007)	
Stroop		Selective attention and inhibition to identify of colors, color words, or font color of a color word as quickly as possible without making errors; test-retest reliability range = 0.67–0.83	Franzen et al. (1987)	
Trails B		Mental set flexibility requiring alternating sequence of connecting number and letter circles (1-A-2-B-3-C); test-retest reliability range = 0.54–0.62	Strauss et al. (2006)	
Wisconsin Card Sorting Test		Cognitive set-shifting to sort cards according to different principles; test-retest reliability range = 0.46–0.64	Lezak (1995)	
Dot counting		Selective attention to count blue circles from a mixed array of green circles, one at a time, aloud, and report the total; test-retest reliability range = 0.51–0.96	Kramer (2011); Lezak (1995)	
1-back		Working memory to decide if location of white square is the same as the previous white square; Cronbach's alpha = 0.04	Kramer (2011)	
Cognitive control set-shifting		Set-shifting to compare two stimuli based on shape, color, or size switching between cues; Cronbach's alpha range = 0.91–0.98.	Kramer (2011)	
Cognitive control flanker		Conflict task to determine if a centrally presented arrow is pointing either to the left or right by pressing the correct arrow key; Cronbach's alpha range = 0.88–0.98.	Kramer (2011)	
Reaction Time	Road Sign Test	Complex reaction time task involving 3- or 6- stimuli requiring visual search and specific reaction to pedestrian- or turn-arrow signs while ignoring distractor; test-retest reliability = 0.56	Deouell et al. (2005); Vance et al. (2007)	
	Reaction Time	Performed in driving simulator simple reaction time to onset of brake lights by release of the accelerator pedal and initiation of brake pedal. Road Sign Test described above performed in simulator with responses by turning wheel or pressing brakes; interrater reliability range = 0.92–0.94	Roenker et al. (2003)	

(continued on next page)

Table 2 (continued)

Domain	Measure	Description of Measure; Psychometric Properties	References
IADL	Timed IADL	A timed objective measure of instrumental activities of daily living performance; test-retest reliability = 0.64	Owsley et al. (2001)
	Self-reported IADL	Self-reported difficulties with instrumental activities of daily living per the African American Health cohort study or the minimum data set home care scales; Chronbach's alpha = 0.80	Miller et al. (2005)
Driving Mobility and Adverse Events	Driving Habits Questionnaire	Assesses driving history yielding composites of driving space and driving difficulty, and identifies driving cessation, test-retest reliability range = 0.60–0.86	Owsley et al. (1999)
	Dangerous maneuvers	Action when a driving instructor had to take control of the wheel or when other drivers had to alter their driving in order to avoid collision during an on-road driving assessment.	Roemaker et al. (2003)
	At fault crashes	State-recorded, at-fault crash records obtained from departments of motor vehicles administration.	Ball et al. (2010)
Well-Being	Center for Epidemiological Studies Scales for Depression	A questionnaire that measures depressive symptoms within the past week; test-retest reliability = 0.54	Radloff (1977)
	Cognitive Self Report Questionnaire	A 25 item questionnaire used to measure perception of cognition, hearing, and everyday functioning; Cronbach's alpha = 0.91	Smith et al. (2009); Spina et al. (2006)
	Health-related quality of life (HRQoL)	A subjective shortened version of SF36 consisting of eight scale scores that measures health-related quality of life using domains of physical functioning, role limitations due to physical functioning, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems, and mental health; Internal consistency reliability range = 0.89–0.94	Gandek et al. (2004); Wolinsky et al. (2009c); Wolinsky et al. (2006b)
	Functional Assessment of Cancer Scale-Cognitive scale	Used to measure symptoms of distress, in individuals with cancer; test-retest reliability = 0.76	Cheung et al. (2014)
	Functional Assessment of Cancer Therapy-Fatigue Scale	Symptom distress for individuals with cancer; test-retest reliability = 0.87	Yellen et al. (1997)
	Spielberger State-Trait Anxiety Inventory Scale (STAI-S)	20-item questionnaire that measures symptoms of distress; test re-test reliability range = 0.31–0.86	Spielberger (2010)
	Self-rated health	Ratings of perceived health on a 5-point likert scale ranging from excellent to poor; interrater reliability = 0.43	Zajacova and Dowd (2011)
Powerful other locus of control Internal locus of control Chance locus of control	Self-efficacy measure that assesses locus of control; test-retest reliability range = 0.74–0.88	Lachman et al. (1982)	

2006; Wolinsky et al., 2013).

2.3.2. Targeted cognitive constructs

To examine if UFOV training demonstrates transfer to other laboratory tasks that measure the same cognitive construct as the training exercises, we quantified effects of training for neural outcomes, speed of processing, and attention. Effects of training were quantified across neural outcomes including pupil diameter (Burge et al., 2013), event related potentials of the P3b amplitude and the N2pc amplitude (O'Brien et al., 2013), and fMRI of the central executive and default mode network (Lin et al., 2016). Speed of processing measures included a composite of everyday speed, Finding As, Trails A, Symbol Digit Modalities Test, Digit Symbol Substitution, Letter Pattern Comparison, and Identical Pictures (Ball et al., 2002; Edwards et al., 2002; Edwards et al., 2005b; Willis et al., 2006; Wolinsky et al., 2013). Measures of attention included the Digit Vigilance and Starry Night Tests (Vance et al., 2007; Wolinsky et al., 2013). Effects were averaged across multiple measures and time points within studies.

2.3.3. Non-targeted cognitive constructs

To examine if UFOV training transfers to other cognitive constructs, we examined effects on cognitive outcomes not practiced in training including memory, executive function, and reaction time. It is important to note UFOV training does not target response time, and the UFOV test is not a reaction time measure. Within each of these domains, effects were averaged across multiple measures within a study. Memory outcomes were assessed across five studies, which included outcomes of the Squires Subjective Memory Questionnaire, Auditory Verbal Learning Test, Rivermead Behavioral Paragraph Recall Test, Benton Visual Retention Test, Rey-O Complex Figure Test, Digit Span, and Spatial Span (Edwards et al., 2002, 2005b; Vance et al., 2007; Von Ah et al., 2012; Wadley et al., 2006). Executive function was assessed by the Controlled Oral Word Association Test, phonemic and categorical

verbal fluency from the EXAMINER battery, Paced Auditory Serial Addition Test, Stroop, Trails B, Wisconsin Card Sorting Test, and working memory as assessed by dot counting and 1-back from the EXAMINER battery (Edwards et al., 2002, 2005b; Lin et al., 2016; Vance et al., 2007; Vance et al., 2012; Wadley et al., 2006; Wolinsky et al., 2013). Reaction time was primarily measured by the Road Sign Test, but also as simple and complex reaction time in a driving simulator (Edwards et al., 2002, 2005b; Roemaker et al., 2003; Vance et al., 2007; Vance et al., 2012; Wadley et al., 2006).

2.3.4. Everyday function

To assess whether UFOV training transfers to relevant real-world tasks, we examined the outcomes of IADL, driving mobility, and adverse driving events. Across several studies, everyday functional performance was objectively measured with the Timed IADL test (Ball et al., 2002; Edwards et al., 2002, 2005b; Lin et al., 2016; Rebok et al., 2014; Vance et al., 2007; Willis et al., 2006). Two studies examined effects on self-reported IADL (Ball et al., 2002; Wolinsky et al., 2013).

2.3.5. Driving mobility and adverse driving events

The Driving Habits Questionnaire was used across two studies in three publications to quantify driving mobility. Adverse driving events including driving cessation, dangerous on-road maneuvers, or at-fault crashes, were assessed in three studies and examined across three to ten years (Ball et al., 2010; Edwards et al., 2009a; Roemaker et al., 2003).

2.3.6. Well-being

To examine whether UFOV training transferred to outcomes of importance to older adults such as well-being and quality of life, we quantified effects across measures of depression (i.e., Center for Epidemiological Studies Depression Scale), the Cognitive Self Report Questionnaire, the SF-36 mental health subscale, the Quality of Life for Cancer Survivors scale, the Functional Assessment of Cancer scale with

subscales assessing cognition and fatigue, Spielberger State-Trait Anxiety Inventory Scale, self-rated health, health-related quality of life, powerful other locus of control, internal locus of control, and chance locus of control (Edwards et al., 2013a, 2015; Von Ah et al., 2012; Wolinsky et al., 2009a, 2009b, 2010, 2009c, 2015).

Qualitative analyses of studies examining other outcomes (e.g., physical mobility, health care expenditures), moderators/mediators of UFOV training, or using secondary analyses to examine subsamples of studies already included, (Belchior et al., 2012; Edwards et al., 2013b; Elliott et al., 2014; Ellis et al., 2014; Kaur et al., 2014; Sharpe et al., 2014; Smith-Ray et al., 2014a, 2014b; Unverzagt et al., 2012; Unverzagt et al., 2007; Valdes et al., 2012; Wolinsky et al., 2009a, 2016) and those identified in the gray literature are also reported (American Automobile Association, 2016; Denning, 2013; Johnston et al., 2015; Sorenson, 2012).

Results across all the studies were examined to address the questions of how long are the trained skills retained and whether the purported benefits of UFOV training have been replicated by researchers other than those selling the product (Institute of Medicine, 2015).

2.4. Analyses

Comprehensive Meta-analysis Software Version 2.0 was used to quantify the effects sizes of UFOV training relative to control groups across studies. Means, standard deviations (or odds ratios for adverse driving events), sample sizes, and p values were gathered from the published articles or by contacting the authors for further information. For studies that included multiple measures or time points to assess the same domain, effect sizes were averaged within study and across time. Publication bias was examined by calculating Egger's regression (Egger et al., 1997), and inspection of funnel plots. If the regression coefficient was significant ($p < 0.05$), then Duval and Tweedie's trim and fill analysis was planned to estimate adjusted effect sizes. In addition, the fail-safe N (N_{fs}) was calculated for each domain to determine how many studies would be needed to make a significant difference no longer significant. Next, each domain was assessed for heterogeneity by using Q statistic. Since Q can be biased by the number of studies (Hardy and Thompson, 1998), we examined I^2 as well to measure the variation between studies (Higgins et al., 2003). I^2 values of 25% were considered low, 50% medium, and 75% high heterogeneity. Random effects models were used to estimate Cohen's d effect sizes. Cohen's d effect sizes were categorized as small ($d = 0.2$), medium ($d = 0.5$), or large ($d = 0.8$).

3. Results

Forest plots from all analyses are shown in Figs. 2–16. Egger's regression and Funnel plots did not reflect publication bias or significant outliers. Across training studies examining UFOV as a proximal outcome ($k = 14$), there was significant heterogeneity, $I^2 = 86.07$, $Q(15) = 107.71$, $p < 0.001$. A significant medium-sized improvement from UFOV training on the targeted proximal outcome was evident, $d = 0.71$, $p < 0.001$, $N_{fs} = 1,074$ (see Fig. 2). The heterogeneity was not unexpected and was further examined by type of control condition, training technique, and health of the sample. Effects on the proximal outcome were quantified by studies that used active control conditions ($k = 9$) vs. those using no-contact controls ($k = 6$), which indicated significant heterogeneity, $I^2 = 86.29$, $Q(15) = 109.47$, $p < 0.001$. Effects of UFOV training relative to active controls showed significant medium improvements, $d = 0.77$, $p < 0.001$, as did studies comparing UFOV training to no-contact conditions, $d = 0.63$, $p < 0.001$ (see Fig. 3). One factor that may account for heterogeneity in effects is whether or not adaptive training techniques were used. Effects of adaptive training ($k = 4$) were examined relative to effects of partially- or non-adaptive training on the proximal UFOV outcome among healthy older adults ($k = 3$). There was significant heterogeneity

among studies using adaptive UFOV training, $I^2 = 89.95$, $Q(7) = 69.71$, $p < 0.001$. Random effects models indicate that adaptive training studies showed significant, large improvements on the proximal outcome, $d = 0.89$, $p < 0.001$, $N_{fs} = 336$ (see Fig. 4). Partially-adaptive training studies showed significant heterogeneity, $I^2 = 82.85$, $Q(2) = 11.66$, $p = 0.003$, and a random effects model yielded significant medium improvements, $d = 0.75$, $p < 0.001$, $N_{fs} = 78$ (see Fig. 5). Training studies examining community-based samples showed significant heterogeneity, $I^2 = 87.02$, $Q(10) = 77.41$, $p < 0.001$, and the random effects model yielded significant large improvements, $d = 0.85$, $p < 0.001$ with an $N_{fs} = 818$ (see Fig. 6). Yet another factor that may contribute to heterogeneity of training is the health of the sample. Among clinical samples there was not significant heterogeneity, $I^2 = 0$, $Q(4) = 1.94$, $p = 0.74$, and training effects were significant, but small, $d = 0.33$, $p < 0.001$ with an $N_{fs} = 26$.

3.1. Targeted cognitive constructs

To examine whether UFOV training improves the targeted cognitive constructs, effects were quantified across neural outcomes, which did not show significant heterogeneity, $I^2 = 0$, $Q(2) = 1.88$, $p.39 = 0.39$. Results indicated significant medium improvements on neural outcomes from UFOV training, $d = 0.69$, $p = 0.009$ (see Fig. 7). Three studies were included and the N_{fs} was 3. For speed of processing, there was not significant heterogeneity, $I^2 = 0$, $Q(6) = 2.84$, $p.83 = 0.83$, and significant small improvements were evident overall, $d = 0.22$, $p < 0.001$ (see Fig. 8). Seven studies were included and the N_{fs} was six. In regard to attention, there was not significant heterogeneity, $I^2 = 0$, $Q(3) < 1$, $p.91 = 0.91$, and results showed significant small improvements, $d = 0.14$, $p.027 = 0.027$ with an N_{fs} of 2 (see Fig. 9).

3.2. Non-targeted cognitive constructs

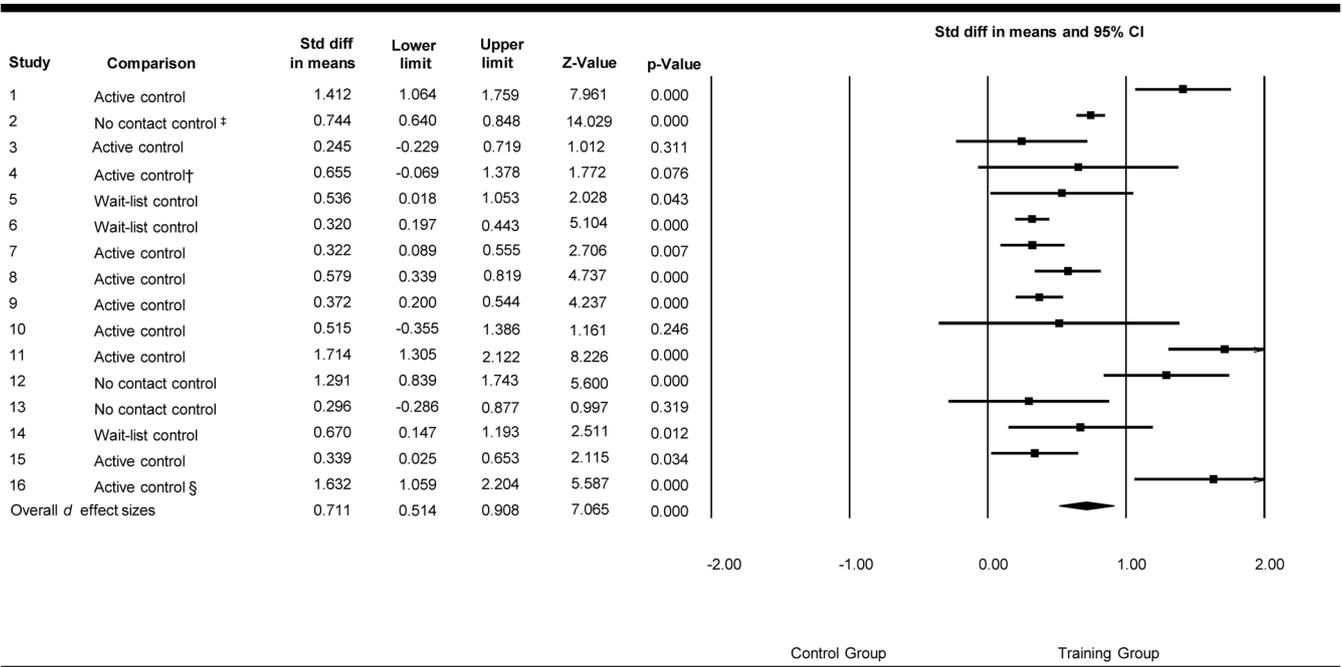
To examine if UFOV training improves other aspects of cognition, effects were quantified for memory which showed no significant heterogeneity, $Q(4) = 5.97$, $p = 0.20$ medium variation, $I^2 = 33.04$, and no significant effects, $d = 0.16$, $p = 0.125$ with a $N_{fs} = 1$. Results are depicted in Fig. 10. Similarly, executive function outcomes did not show significant heterogeneity, $I^2 = 0$, $Q(8) = 6.72$, $p = 0.56$ or significant effects, $d = 0.09$, $p = 0.11$ with a N_{fs} of 0 (see Fig. 11). Reaction time outcomes did not show significant heterogeneity, $I^2 = 0$, $Q(4) = 2.03$, $p = 0.73$, or effects of training, $d = 0.04$, $p = 0.662$ with a N_{fs} of 0 (see Fig. 12).

3.3. Everyday function, driving, and well-being

With regard to IADL, there was no significant heterogeneity, $I^2 = 0$, $Q(7) = 6.59$, $p = 0.47$ with random effects model showing small significant improvements, $d = 0.27$, $p < 0.001$ with a N_{fs} of 29. Results are depicted in Fig. 13. To further examine if UFOV training improves everyday function, effects were quantified for driving mobility which showed no significant heterogeneity, $I^2 = 0$, $Q(2) = 0.08$, $p = 0.961$, and a small significant effect size, $d = 0.36$, $p = 0.038$ with a N_{fs} of 0. As only two studies were included, a funnel plot could not be examined. Adverse driving events showed no significant heterogeneity, $I^2 = 0$, $Q(2) = 0.39$, $p = 0.822$ and showed a significant effect size, $OR = 0.50$, $p < 0.001$, with a N_{fs} of 9, indicating those randomized to UFOV training were 49% less likely to experience an adverse driving event. Across well-being indices, there was no significant heterogeneity, $I^2 = 0$, $Q(6) = 11.00$, $p.09 = 0.09$, and results showed a significant small improvement, $d = 0.21$, $p.044 = 0.044$ with a N_{fs} of 7 (see Fig. 16).

3.4. Qualitative analyses

Of the 17 different randomized clinical trials of UFOV training



Note. Driving instructor/Simulator=driving instructor and simulator training; Proximal outcome is Useful Field of View Test performance; ¹Vance et al. 2007 (N=159); ²Ball et al. 2002, Rebok et al. 2014, Willis et al. 2006 (N=2802); ³Akinwuntan et al. 2010 (N=69); ⁴Belchior et al. 2013 (N=45); ⁵Edwards et al. 2015 (N=60); ⁶Edwards et al. 2013 (N=87); ⁷Wolinsky et al. 2013 (N=322) on-site training; ⁸Wolinsky et al. 2013 (N=306) on-site training with booster; ⁹Wolinsky et al. 2013 (N=350) at-home training; ¹⁰Lin et al. 2016 (N=21); ¹¹Edwards et al. 2005 (N=126); ¹²Edwards et al. 2002 (N=91); ¹³Vance et al. 2012 (N=46); ¹⁴Von Ah et al. 2012 (N=82); ¹⁵Wadley et al. 2006 (N=164); ¹⁶Roemaker et al. 2003 (N=95). Outcome is Useful Field of View total of three subtests, except for Belchior et al. 2013[†] in which outcome is average of Useful Field of View subtests 1-3. †Outcome averaged across 1, 2, 5 and 10 years; §Outcome averaged across post-test and 18-months.

Fig. 2. Forest Plot for Useful Field of View Training Effects on Proximal Outcome.

identified in the systematic review, four examined how long the trained skills and transfer are retained across multiple publications including intervals of one year, 18-months, two-years, five-years, and ten years (Ball et al., 2002; Edwards et al., 2005b; Roemaker et al., 2003; Wolinsky et al., 2013). Studies indicated that proximal effects (i.e., trained skills) on UFOV endured at 18-months ($d = 1.63$), two-years ($d = 0.86$), five-years ($d = 0.76$), and at ten years with a medium effect size of 0.66 (Rebok et al., 2014). All four of these studies showed significant transfer of training longitudinally across outcomes of everyday function, driving mobility, adverse driving events, and well-being (Ball et al., 2002; Edwards et al., 2009a, 2009b; Rebok et al., 2014; Roemaker et al., 2003; Willis et al., 2006; Wolinsky et al., 2009a, 2009b, 2010, 2009c, 2015).

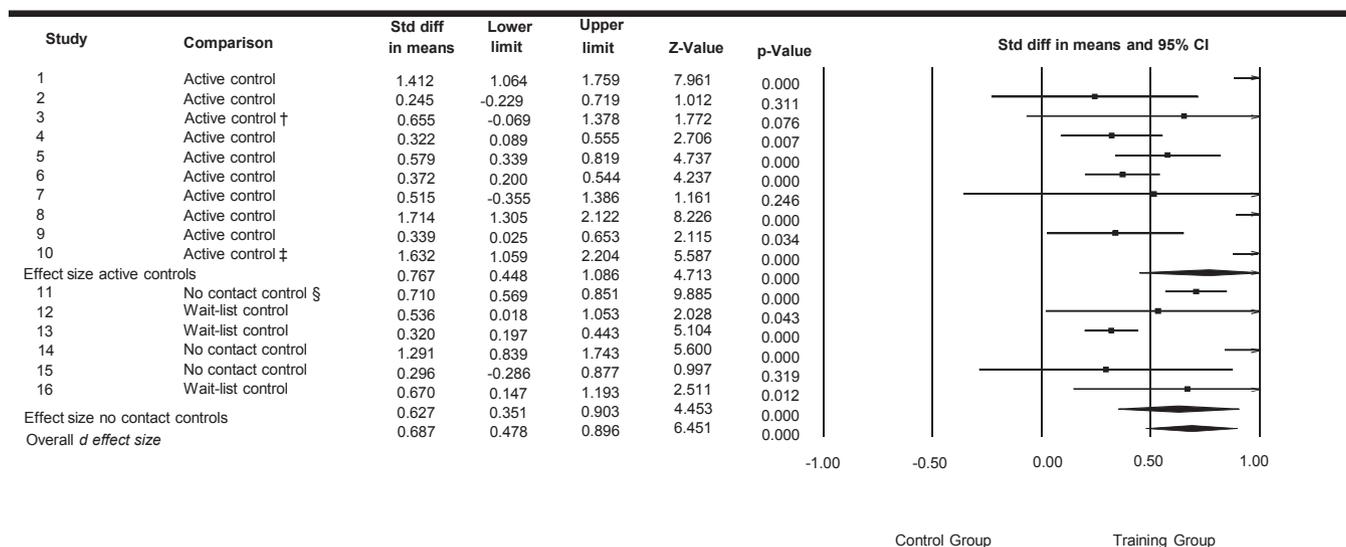
Of the 17 different randomized clinical trials identified, nine were conducted by researchers who had no commercial interest in the UFOV training program (Akinwuntan et al., 2010; Belchior et al., 2013; Burge et al., 2013; Edwards et al., 2013a, 2015; Lin et al., 2016; Vance et al., 2012; Von Ah et al., 2012; Wolinsky et al., 2013), all of which showed significantly improved outcomes.

Thirteen publications on UFOV training were identified in the systematic review, but were not included in quantitative analyses because 1) the analyses were of subsamples of studies already included; 2) the analyses examined moderators or mediators of training gains from studies already included; or 3) the outcomes did not fit within the planned analyses and were not examined in at least three studies (Belchior et al., 2012; Edwards et al., 2013b; Elliott et al., 2014; Ellis et al., 2014; Kaur et al., 2014; Sharpe et al., 2014; Smith-Ray et al.,

2014a; Smith-Ray et al., 2014b; Unverzagt et al., 2012; Unverzagt et al., 2007; Valdes et al., 2012; Wolinsky et al., 2009a, 2016).

Five of these publications examined subsamples of the ACTIVE, SKILL (Staying Keen in Later Life) or IHAMS (Iowa Healthy and Active Minds Study) studies, which were already included in analyses. Four of these publications indicated that UFOV training was effective in older adults with memory impairment, mild cognitive impairment, heart failure, or vision impairment (Elliott et al., 2014; Ellis et al., 2014; Unverzagt et al., 2007; Valdes et al., 2012). Wolinsky et al. (2016) further examined UFOV training effects on a neuropsychological composite including six measures of speed, attention, and executive function, and found that UFOV training did not enhance cognition broadly. These findings are consistent with quantitative analyses above.

Four of the studies included in our qualitative analyses examined moderators or mediators of UFOV training gains, using samples from studies included in quantitative analyses. Three of these examined beliefs and expectations in relation to training gains (Belchior et al., 2012; Kaur et al., 2014; Sharpe et al., 2014). Kaur found that individuals who were less likely to rate the UFOV training as enjoyable and who felt their mental abilities did *not* improve from UFOV training, actually improved more (Kaur et al., 2014). Thus, participants' expectations did not correspond to training gains. Similarly, Sharpe et al. (2014) indicated that self-efficacy was not associated with UFOV training gains. With regard to mediators of training gains, Edwards et al. demonstrated that the transfer of UFOV training to improved IADL was completely mediated by proximal improvements in divided attention (Edwards et al., 2013b).



Note. ¹Vance et al. 2007 (N=159), social and computer contact; ²Akinwuntan et al. 2010 (N=69), memory/reasoning training; ³Belchior et al. 2013 (N=45), tetris; ⁴Wolinsky et al. 2013 (N=322) on-site training, active control includes crossword puzzles; ⁵Wolinsky et al. 2013 (N=306) on-site training with boosters, active control includes crossword puzzles; ⁶Wolinsky et al. 2013 (N=350) at-home training, active control includes crossword puzzles; ⁷Lin et al. 2016 (N=21), mental leisure activities; ⁸Edwards et al. 2005 (N=126), social and computer contact; ⁹Wadley et al. 2006 (N=164), social and computer contact; ¹⁰Roenker et al. 2003 (N=95), driving instructor/simulator training; ¹¹Ball et al. 2002 (N=1,283), Rebok et al. 2014 (N=604), Willis et al. 2006 (N=938); ¹²Edwards et al. 2015 (N=60); ¹³Edwards et al. 2013 (N=87); ¹⁴Edwards et al. 2002 (N=91); ¹⁵Vance et al. 2013 (N=46); ¹⁶Von Ah et al. 2012 (N=82). Outcome is total of three Useful Field of View subtests except for Belchior et al. 2013† in which outcome is average of Useful Field of View subtests 1 and 3. †Outcome combined post-test and 18-month time points. §Outcome averaged across 1, 2, 5, and 10 years.

Fig. 3. Forest Plot for Active vs. No Contact Control Group on Proximal Outcome.

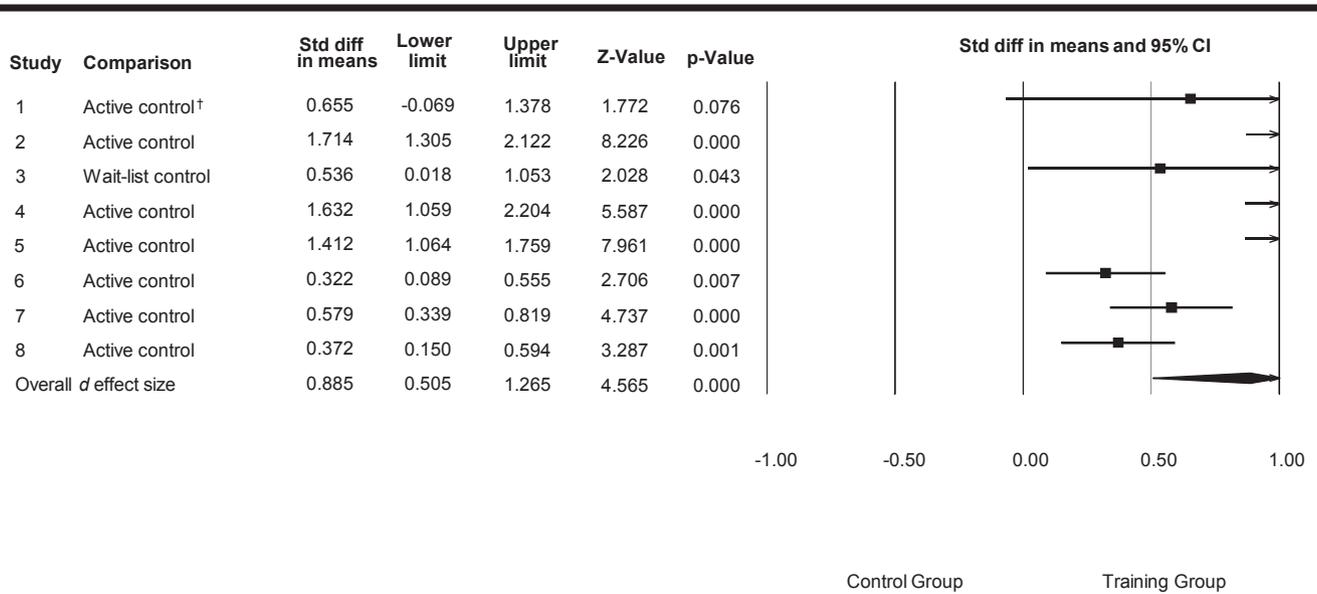
Two studies not included in the quantitative analyses showed that UFOV training improved performance on measures of physical mobility, including gait speed and the Timed Up and Go Test (Smith-Ray et al., 2014a, N = 51, *d* = 0.92; Smith-Ray et al., 2014b, N = 45, *d* = 0.48). Unverzagt and colleagues examined the combined effect of any type of cognitive training from the ACTIVE study on dementia incidence across five years. There were not significant effects, but UFOV training effects were combined with other techniques and the number of participants meeting the dementia criteria was small at five years limiting power (Unverzagt et al., 2012). Wolinsky et al. found that those randomized to UFOV training in ACTIVE would have significantly less predicted medical care expenditures across five years (Wolinsky et al., 2009a).

Four studies of UFOV training were identified in the gray literature search, three of which were unpublished (American Automobile Association, 2016; Denning, 2013; Johnston et al., 2015; Sorenson, 2012). These studies found similar results as indicated from quantitative analyses. One was not a randomized trial, but showed a 30% reduction in adverse driving events subsequent to UFOV training (i.e., collision claims) among 7000 adult drivers (American Automobile Association, 2016). Denning (2013) randomized 11 older adults to UFOV training and 10 to an active control condition of crossword puzzles: results showed significant neural effects (i.e., fMRI resting state functional connectivity) subsequent to training. The third study identified in the gray literature was a randomized trial of UFOV training among 32 adults aged 66, on average, and results indicated enhanced UFOV and Trails A, but no improvements on Trails B or Ravens Progressive Matrices (Sorenson, 2012). Effect sizes were calculated from pre- to post- within the UFOV training group, Trails A *d* = 0.36, Trails B *d* = 0.01, UFOV *d* = 0.88, Ravens Progressive Matrices *d* = 0.03. Among 42 older adults, Johnston et al. (2015) examined the effects of UFOV training on Trails A (*d* = 0.50) and B (*d* = 0.83) and Hazard

Perception Test (*d* = 0.02), but effects were not statistically significant. However, participants completed less than 5 h of training, on average (across three different exercises, only one of which was UFOV training), and the control group performed significantly better on the outcomes at baseline.

4. Discussion

Systematic review and meta-analyses of 44 published studies from 17 different randomized clinical trials published in peer-reviewed journal articles indicate that UFOV training has multiple benefits across a variety of outcomes. Publication bias was not evident from Egger's regression or inspection of funnel plots. A gray literature search and qualitative analyses of unpublished studies were also not indicative of publication bias. Results of quantitative analyses showed overall medium gains on the targeted proximal outcome, but large effects were seen for adaptive training techniques and in community-based samples. UFOV training has medium effect sizes relative to both active control conditions and to no-contact controls. Although effects are attenuated relative to healthy older adults, UFOV training is efficacious among individuals with chronic diseases associated with concomitant cognitive decline (i.e., HIV, Parkinson's disease, stroke, and breast cancer). UFOV training also significantly enhances neural outcomes and the targeted cognitive constructs of speed of processing and attention with small effect sizes. Thus, training transfers to other laboratory tasks that measure the same cognitive construct. Of most importance, UFOV training transfers to real-world tasks, including those that are vital to older adults' maintained independence, with significant, lasting effects. Although a common critique of cognitive training is that it does not transfer, UFOV training significantly improves performance of IADL across multiple clinical trials, demonstrating far transfer. Of particular meaningfulness to older adults, UFOV training prolongs driving

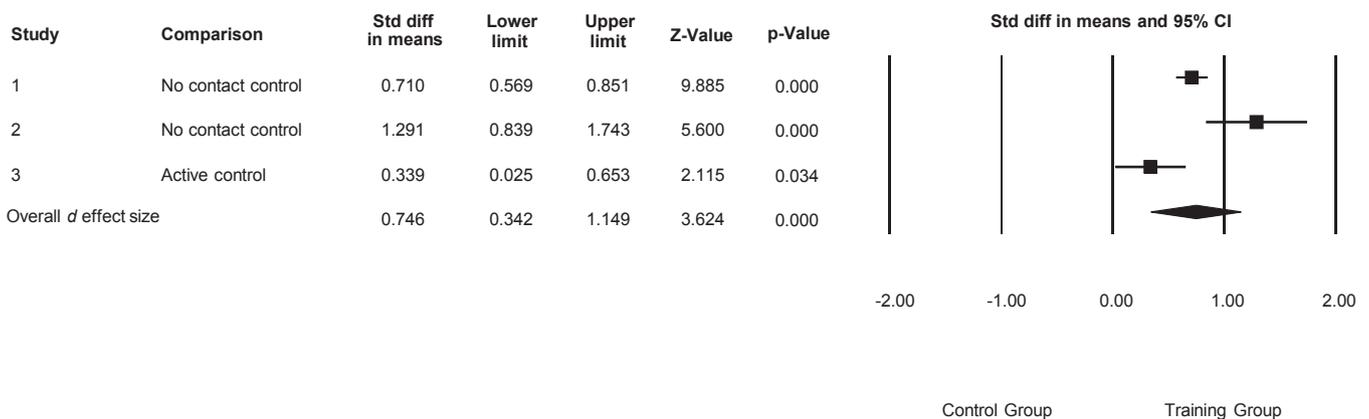


Note. ¹Belchior et al., 2013 (N=45), tetris; ²Edwards et al., 2005 (N=126), social and computer contact; ³Edwards et al., 2015 (N=60); ⁴Roenker et al., 2003 (N=95), driving instructor/simulator training, averaged across post-test and 18 months; ⁵Vance et al., 2007 (N=159), social and computer contact; ⁶Wolinsky et al. 2013 (N=322), on-site training, active control includes crossword puzzles; ⁷Wolinsky et al. 2013 (N=306), on-site training with boosters, active control includes crossword puzzles; ⁸Wolinsky et al. 2013 (N=350), at-home training, active control includes crossword puzzles. Outcome is Useful Field of View Test Performance total of three subtests except for Belchior et al. 2013[†] in which outcome is average of Useful Field of View subtests 1-3.

Fig. 4. Forest Plot for Useful Field of View Adaptive Training on Proximal Outcome.

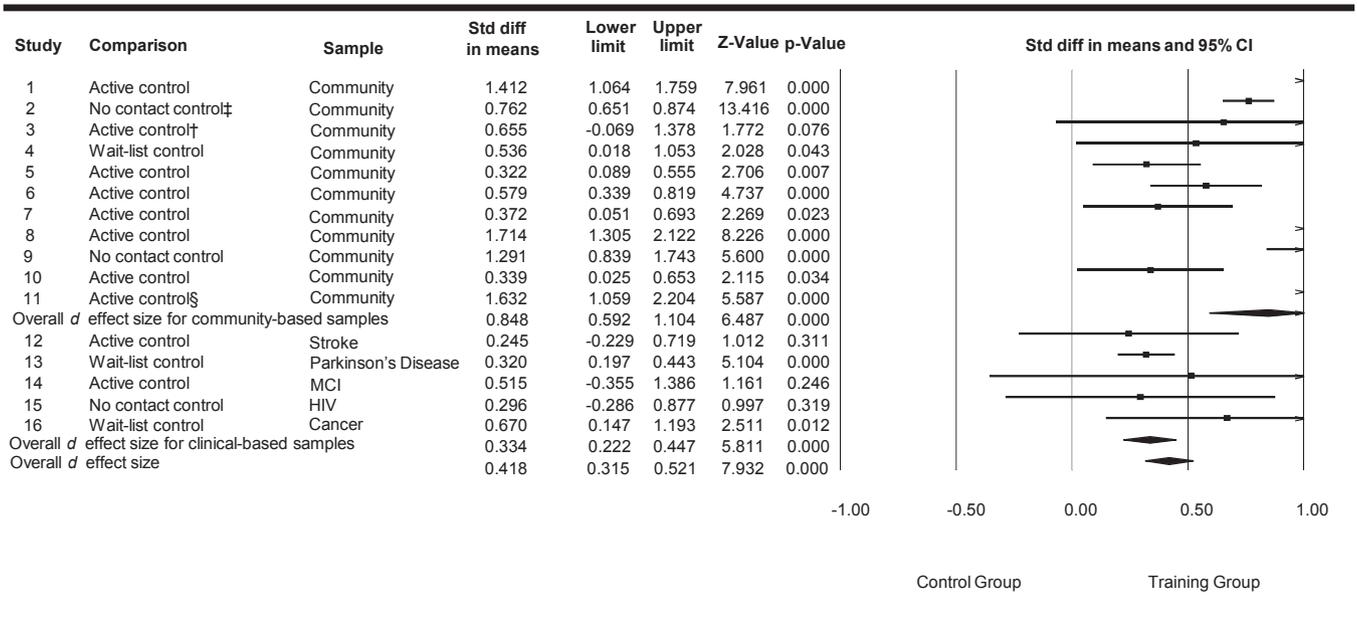
mobility and enhances driving safety for up to seven years after training. Overall, results indicate that those randomized to UFOV training are 49% less likely to experience an adverse driving event. Moreover, many aspects of health and well-being are enhanced from UFOV training, with significant effects evident up to five years later. Trials of UFOV training have shown that the trained skills are retained

across 10 years, and that the transfer of training is evident three to 7 years after training. Nine of the randomized clinical trials (50% of those identified from systematic review) were conducted by researchers without financial interests, and demonstrated significant UFOV training effects. Given these findings, UFOV training meets all five of the criteria for cognitive training advanced by the Institute of Medicine (Institute of



Note. ¹Ball et al. 2002 (N=1,283), Willis et al. 2006 (N=604), Rebok et al. 2014 (N=938) averaged across 1, 2, 5, and 10 years; ²Edwards et al. 2002 (N=91); ³Wadley et al. 2006 (N=164), social and computer contact. Outcome is Useful Field of View Test Performance total of three subtests.

Fig. 5. Forest Plot for Useful Field of View Partially-Adaptive Training on Proximal Outcome.



Note. ¹Vance et al. 2007 (N=159); ²Ball et al. 2002 (N=1,283); ³Rebok et al. 2014 (N=604); ⁴Willis et al. 2006 (N=938); ⁵Belchior et al. 2013 (N=45); ⁶Edwards et al. 2015 (N=60); ⁷Wolinsky et al. 2013 (N=322), on-site training; ⁸Wolinsky et al. 2013 (N=306), on-site training with boosters; ⁹Wolinsky et al. 2013 (N=350), at-home training; ¹⁰Edwards et al. 2005 (N=126); ¹¹Edwards et al. 2002 (N=91); ¹²Wadley et al. 2006 (N=164); ¹³Roegner et al. 2003 (N=95); ¹⁴Akinwuntan et al. 2010 (N=69); ¹⁵Edwards et al. 2013 (N=87); ¹⁶Lin et al. 2016 (N=21); ¹⁷Vance et al. 2012 (N=46); ¹⁸Von Ah et al. 2012 (N=82); MCI = Mild Cognitive Impairment; HIV = Human Immunodeficiency Virus; †Combined across 1, 2, 5, and 10 years; Outcome is total of three Useful Field of View subtests except for Belchior et al. 2013† in which outcome is average of Useful Field of View subtests 1-3; §outcome averaged across post-test and 18 months.

Fig. 6. Forest Plot for Useful Field of View Training Effects in Community-based vs. Clinical Samples on Proximal Outcome.

Medicine, 2015).

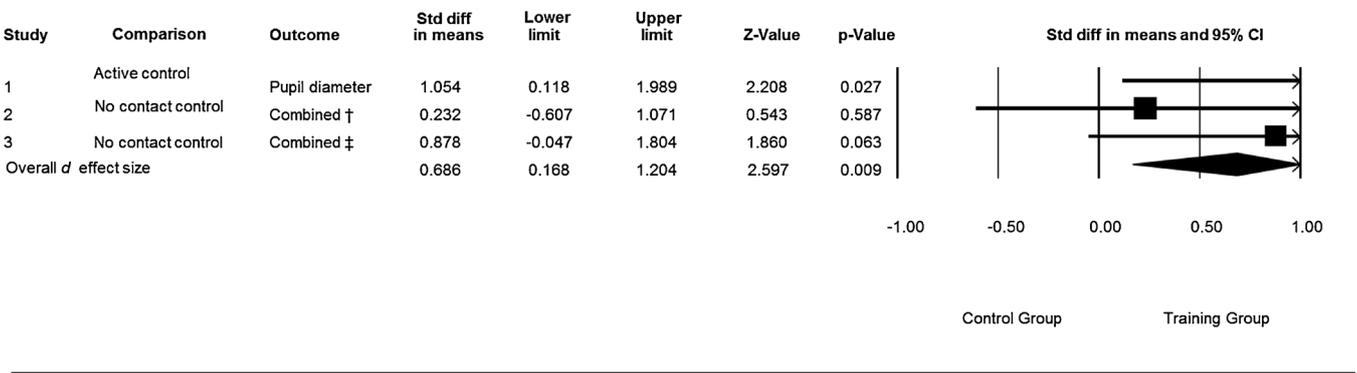
4.1. Adaptive training

It is important to note that training gains may vary by the type of technique used. Our results overall show large effects of adaptive training and medium effects of partially adaptive training, but the magnitude of effects were close. Wadley et al. found adaptive UFOV training to be 1.35 times more efficacious as non-adaptive techniques in support of the model of adult plasticity (Lovden et al., 2010). Unfortunately, in our analyses, the number of training sessions is confounded with technique. The ACTIVE study found significant effects of training dose, with broader transfer among those who completed booster UFOV training. In ACTIVE, UFOV training included 5 non-

adaptive sessions and 5 adaptive training sessions, and those randomized to booster were offered an additional 8 adaptive sessions. Thus, the number of adaptive sessions ranged between 5–13. It remains unclear if the broader transfer observed in the booster condition was due to the adaptive nature or additional number of training sessions, or both.

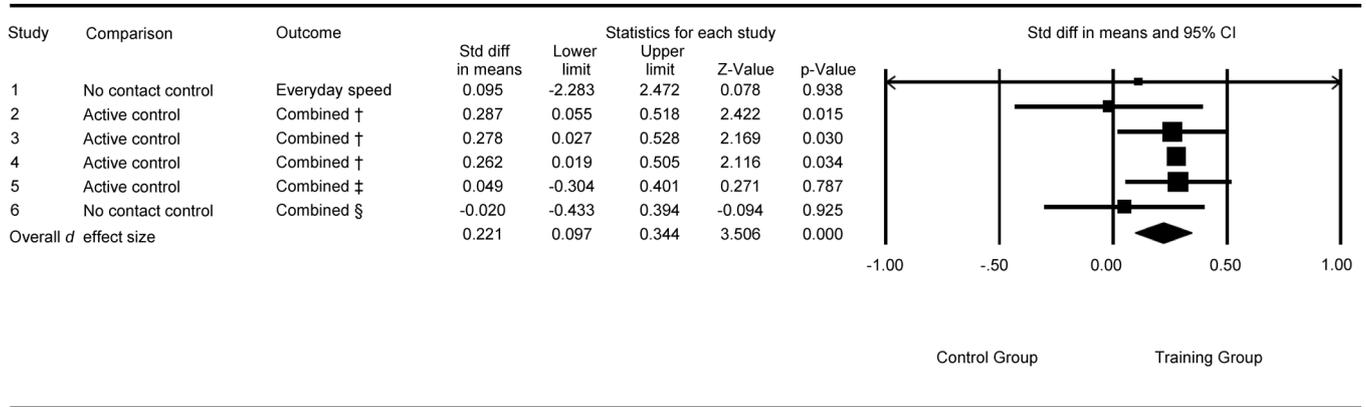
4.2. Transfer of training

One Institute of Medicine specified criterion was that the training program demonstrate transfer of training to other laboratory tasks that measure the same cognitive construct. UFOV training meets this criterion as the targeted cognitive constructs of speed of processing and attention were significantly enhanced with small effects and neural



Note. ¹Burge et al. 2013 (N=20); ²O'Brien et al. 2013 (N=22); ³Lin et al. 2016 (N=21); †Combined = event related potentials of the P3b amplitude and the N2pc amplitude; ‡Combined = fMRI of the central executive and default mode networks.

Fig. 7. Forest Plot for Useful Field of View Training Effects on Neural Outcomes.



Note. ¹Ball et al. 2002 (N=1,283), Willis et al. 2006 (N=604), Rebok et al. 2014 (N=938) averaged across 1, 2, 5, and 10 years; ²Wolinsky et al. 2013 (N=350), at-home training; ³Wolinsky et al. 2013 (N=306), on-site training with boosters; ⁴Wolinsky et al. 2013 (N=322), on-site training; ⁵Edwards et al. 2005 (N=126); ⁶Edwards et al. 2002 (N=91); †Combined outcome = Symbol Digit Modalities Test and Trails A; ‡Combined outcome = Digit Symbol Substitution Test, Letter Pattern Comparison, Trails A; §Combined outcome = Digit Symbol Substitution Test, Finding As, Identical Pictures, Letter Pattern Comparison, Trails A.

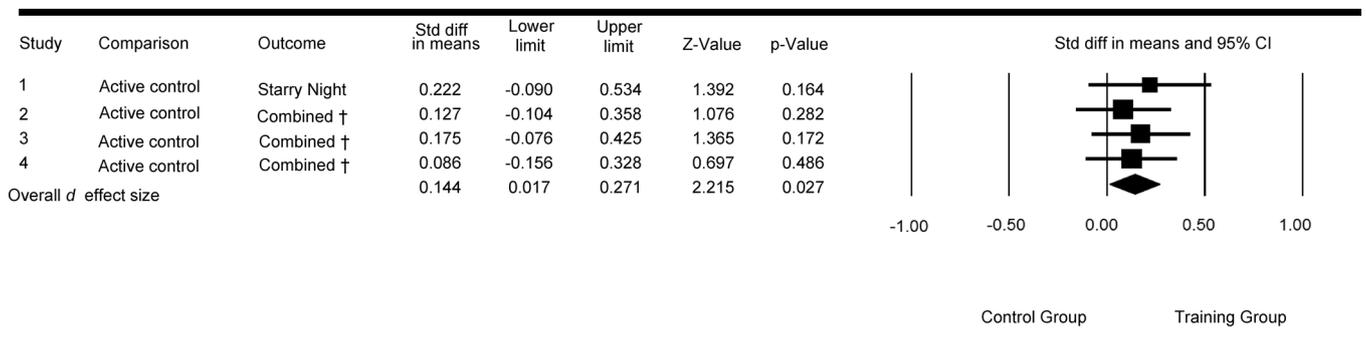
Fig. 8. Forest Plot for Useful Field of View Training Effects on Speed of Processing.

outcomes showed medium effects. However, a limitation is that these outcomes are relatively understudied and N_{fs} values were small, indicating further research is warranted to confirm effects on neural outcomes as well as measures of speed of processing and attention that are not practiced in training. Forthcoming neural studies may strengthen these findings providing more conclusive evidence. Such work would help to delineate the underlying mechanisms of UFOV training and would further clarify if UFOV training is enhancing speed, divided attention, or both. ERP studies and mediation analyses indicate that UFOV training may primarily enhance attention (Edwards et al., 2013b; O'Brien et al., 2013). Future research should identify the mechanisms of effective cognitive interventions, which is necessary to advance the field. By targeting training exercises toward the mechanism(s) most strongly related to improved cognition and particularly everyday function, it may be possible to maximize the effects of cognitive training to improve older adults' functioning as well as public health overall.

We also examined non-targeted cognitive domains. There was no evidence that UFOV training enhances memory, executive function, or reaction time. A valid critique of cognitive training may be that effects do not consistently generalize to other broader cognitive abilities (Simons et al., 2016). At the same time, it could be that existing neuropsychological measures were intended to detect brain damage, and could be insensitive to training gains. However, of more relevance is

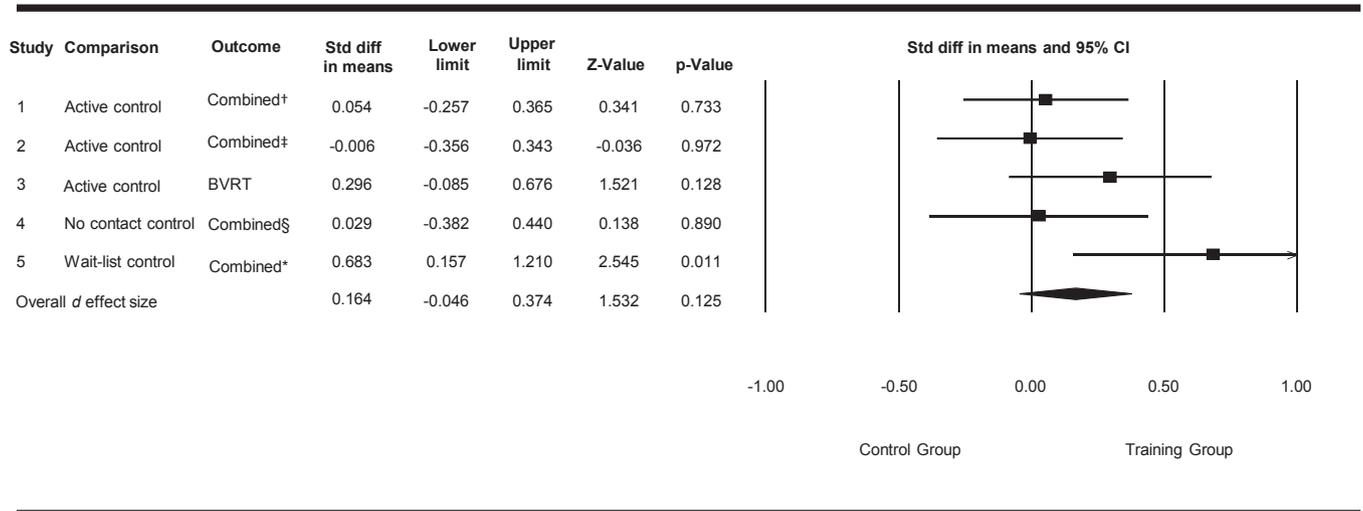
whether or not cognitive training gains translate to real-world benefits.

UFOV training shows transfer of training to relevant real-world tasks, meeting the Institute of Medicine criterion. Across nine published studies from five different randomized clinical trials, UFOV training has transferred to improved IADL performance. Across 10 years (which was ~7 years after training), UFOV training resulted in participants rating their IADL difficulties as lower. The ability to perform IADL is key to older adults' maintained independence. Thus, any intervention that can improve IADL is of great value. Although most cognitive training is criticized for not transferring to improved function, in reality it is rarely measured as an outcome (Kelly et al., 2014). Functional outcomes, including both performance-based and subjective ratings, should be assessed in future cognitive training research. Given that functional decline is a hallmark of dementia (Ratner and Atkinson, 2015), the evidence that UFOV training shows far transfer to improved everyday function is particularly important and meaningful. UFOV training very well may delay the onset of dementia as suggested by recent analyses (Edwards et al., 2017). Even small effects to delay functional impairment and dementia are clinically meaningful in that if an intervention could delay the onset of Alzheimer disease by only one year, there would be a reduction of 9.2 million cases over the next 35 years (Brookmeyer et al., 2007), substantially lessening disease burden and associated costs.



Note. ¹Vance et al. 2007 (N=159); ²Wolinsky et al. 2013 (N=322), on-site training; ³Wolinsky et al. 2013 (N=306), on-site training with boosters; ⁴Wolinsky et al. 2013 (N=350), at-home training. †Combined outcome = Digit Vigilance Test errors and Digit Vigilance Test time.

Fig. 9. Forest Plot for Useful Field of View Training Effects on Attention.



Note. ¹Vance et al., 2007 (N=159); ²Edwards et al., 2005 (N=126); ³Wadley et al. 2006 (N=164); ⁴Edwards et al., 2002 (N=91); ⁵Von Ah et al. 2012 (N=82); BVRT = Benton Visual Retention Test; [†]Combined outcome = BVRT and Rey-O Complex Figure Test; [‡]Combined outcome = Digit Span and Spatial Span; [§]Combined outcome = BVRT, Digit Span, and Rey-Osterrieth Complex Figure Test; ^{*}Combined = Auditory Verbal Learning Test Immediate and Delayed recall, Squires Subjective Memory Questionnaire

Fig. 10. Forest Plot for Useful Field of View Training Effects on Memory.

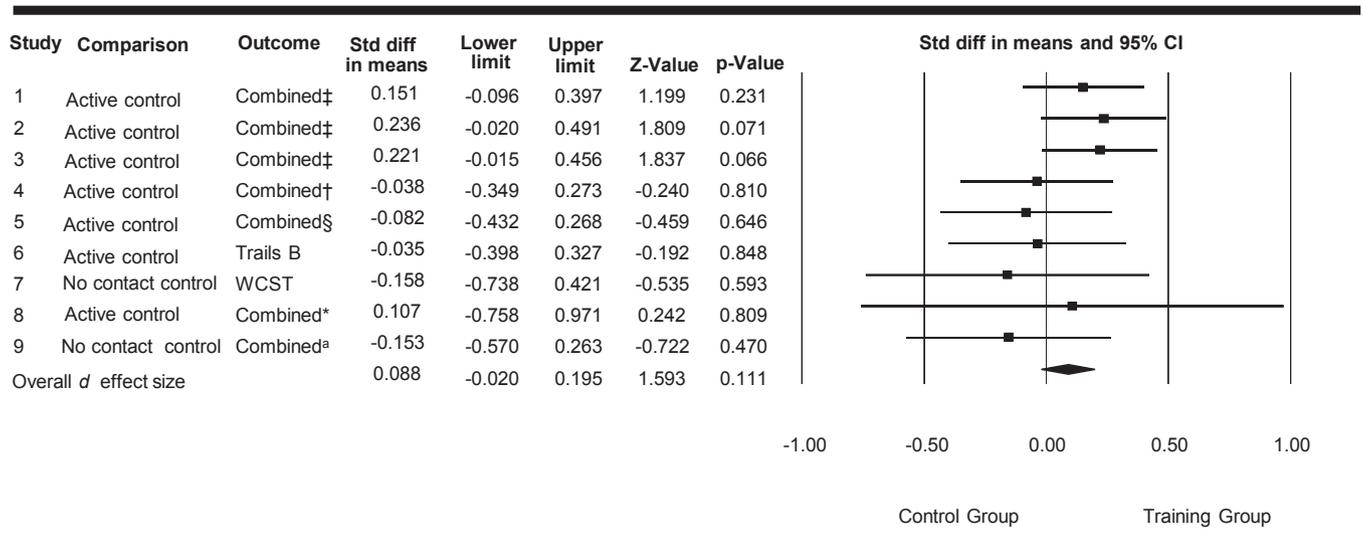
4.3. Why the debate?

Given the compelling evidence presented here and favorable conclusions of several other reviews (Hill et al., 2017; Hindin and Zelinski, 2012; Kelly et al., 2014; Kueider et al., 2012; Lampit et al., 2014; Lampit et al., 2015), one may ask why is the value of cognitive training, UFOV training in particular, being debated? Critics assert that cognitive training effects can be attributed to beliefs and expectations, dismiss the effects of training because they are not supported by theory, question

the clinical meaningfulness of observed transfer of training to real-world outcomes (i.e., driving), and declare that results are not valid because statistical corrections for multiple comparisons were not applied (Foughi et al., 2016; Gamache and Laforce, 2016; Ratner and Atkinson, 2015; Simons et al., 2016). We address these critiques below.

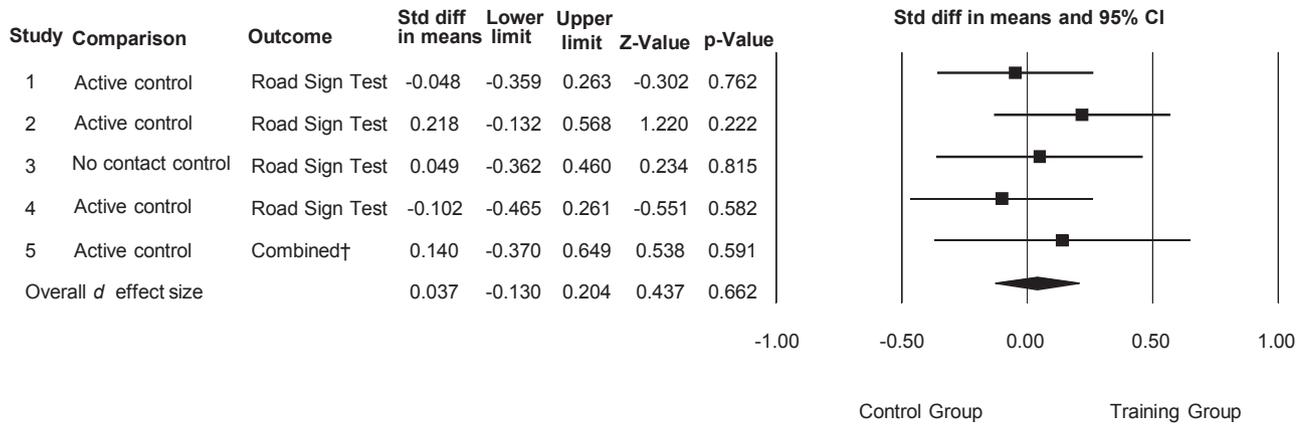
4.3.1. Expectations and beliefs

Critics of cognitive training have asserted that effects can be explained by participants' expectations or beliefs (Foughi et al., 2016;



Note. ¹Wolinsky et al., 2013 (N=322), on-site training; ²Wolinsky et al., 2013 (N=306), on-site training with booster; ³Wolinsky et al., 2013 (N=350), at-home training; ⁴Vance et al. 2007 (N=159); ⁵Edwards et al., 2005 (N=126); ⁶Wadley et al. 2006 (N=164); ⁷Vance et al., 2012 (N=46); ⁸Lin et al., 2016 (N=21); ⁹Edwards et al., 2002 (N=91); WCST = Wisconsin Card Sorting Test; [‡]Combined outcome = Controlled Oral Word Association Test and Trails B; [†]Combined outcome = Trails B, Paced Auditory Serial Addition Test; [§]Combined outcome = Stroop Test and Trails B; ^{*}Combined outcome = phonemic and category fluency, dot counting, set-shifting, and flanker; [§]Combined outcome = Stroop Test, Trails B, and verbal fluency.

Fig. 11. Forest Plot for Useful Field of View Training Effects on Executive Function.



Note. ¹Vance et al. 2007 (N=159); ²Edwards et al. 2005 (N=126); ³Edwards et al. 2002 (N=91); ⁴Wadley et al. 2006 (N=164); ⁵Roemer et al. 2003 (N=95); †Combined outcome = Simple Reaction Time, Choice Reaction Time, and Road Sign Test performed in driving simulator at post-test and 18 months.

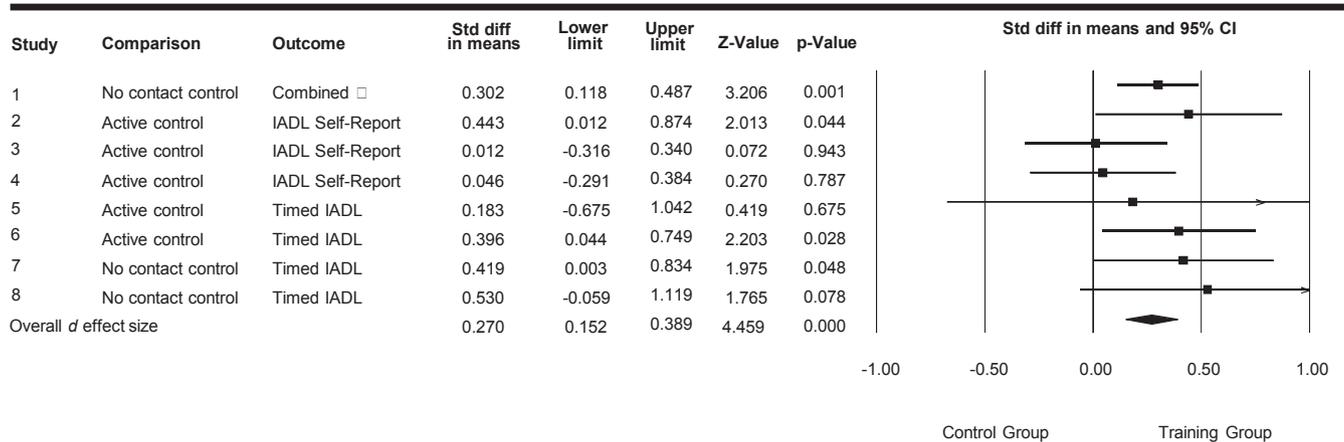
Fig. 12. Forest Plot for Useful Field of View Test Training Effects on Reaction Time.

Simons et al., 2016), a position supported by psychological literature such as the expectancy value theory (Guo et al., 2017). This hypothesis was directly addressed in analyses of two UFOV training studies. In contrast to the expectation/beliefs hypothesis, results showed that older adults who did *not* believe UFOV training improved their mental abilities tended to benefit the most (Kaur et al., 2014). Furthermore, self-efficacy had no bearing on older adults' benefits from UFOV training (Sharpe et al., 2014), in contrast to other cognitive training techniques (Payne et al., 2012). Because UFOV training is an implicit technique, it is likely less affected by beliefs or perceptions than explicit techniques such as memory training (Sharpe et al., 2014). The results of this meta-analysis further demonstrate that the effects of UFOV training relative to active control groups were *not* smaller than effects relative to no contact controls, which is in direct contrast to the expectations/beliefs hypothesis. Another recent meta-analysis showed similar results: there were no differences in the effects of computerized cognitive training as

compared to active- versus no-contact control groups (Hill et al., 2017). There is no evidence that expectations and beliefs drive UFOV training effects, counter to critiques (Simons et al., 2016). Furthermore, it is important to note that Edwards et al. demonstrated that the transfer of UFOV training to improved IADL performance was completely mediated by proximal training gains, which accounted for 87% of the variance (Edwards et al., 2013b). In other words, the transfer of training to improved everyday functional performance can be attributed to UFOV performance improvements. Overall, studies indicate that UFOV training gains do not correspond with beliefs or expectations, but rather transfer of training can be attributed to proximal gains. Thus, expectations or beliefs are not likely driving UFOV training effects.

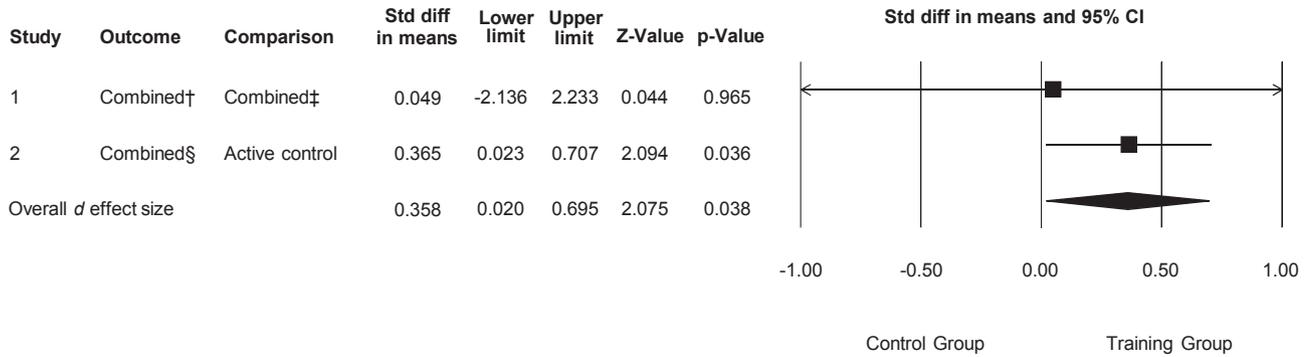
4.3.2. Traditional theory

One reason for the ongoing debate is that cognitive training data challenge long-held beliefs about transfer of learning and fluid



Note. ¹Ball et al., 2013 (N=1,283), Rebok et al., 2014 (N=604), Willis et al., 2006 (N=938) combined across 1, 2, 3, 5 and 10 years; ²Wolinsky et al., 2015 (N=286), on-site training with boosters; ³Wolinsky et al., 2015 (N=330), at-home training; ⁴Wolinsky et al. 2015 (N=305), on-site training; ⁵Lin et al., 2016 (N=21); ⁶Edwards et al., 2005 (N=126); ⁷Edwards et al., 2002 (N=91); ⁸Vance et al., 2012 (N=46). IADL = Instrumental activities of daily living; † Includes IADL Self-Report and Timed IADL.

Fig. 13. Forest Plot for Useful Field of View Training Effects on Instrumental Activities of Daily Living.



Note. ¹Ball et al. 2002 (N=959), Ross et al. 2015 (N=696), ²Edwards et al. 2009 (N=134); †Combined outcomes included driving exposure, driving frequency, and driving space across one to five years; ‡Combined comparison includes memory training and no contact control groups; §Combined outcomes included driving exposure and driving space.

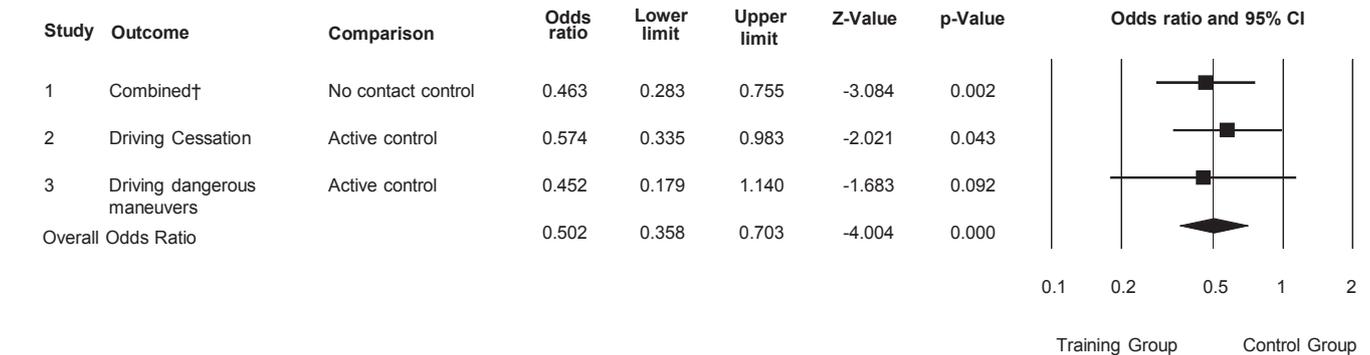
Fig. 14. Forest Plot for Useful Field of View Training Effects on Driving Mobility.

intelligence. Some have argued that the transfer of cognitive training is impossible, based upon the specificity of learning theory, which was advanced by Thorndike over 100 years ago (Gamache et al., 2010; Gamache and Laforce, 2016). Similarly, according to traditional theories of intelligence, fluid intelligence is not affected by education or experience, and thus it is not possible to improve actual fluid abilities by training (e.g., Hambrick, 2014). Scientists from this perspective dismiss gains derived by cognitive training on the proximal outcomes as merely performance improvements that are due to practice. According to this perspective, in order to demonstrate that cognitive training actually improves cognition (i.e., fluid intelligence), performance on tasks that were not practiced in training should also improve. Addressing this critique, the present systematic meta-analysis of UFOV training showed that both speed of processing and attention on tasks not directly practiced in training were improved across studies and UFOV training showed transfer to real-world abilities. Perhaps rather than dismissing cognitive training because it doesn't fit these existing paradigms, we should allow the data to inform our existing understanding of cognition and learning. Notably, efforts at advancing models of fluid intelligence are being made (Kievit et al., 2016).

4.3.3. Clinical meaningfulness of effects

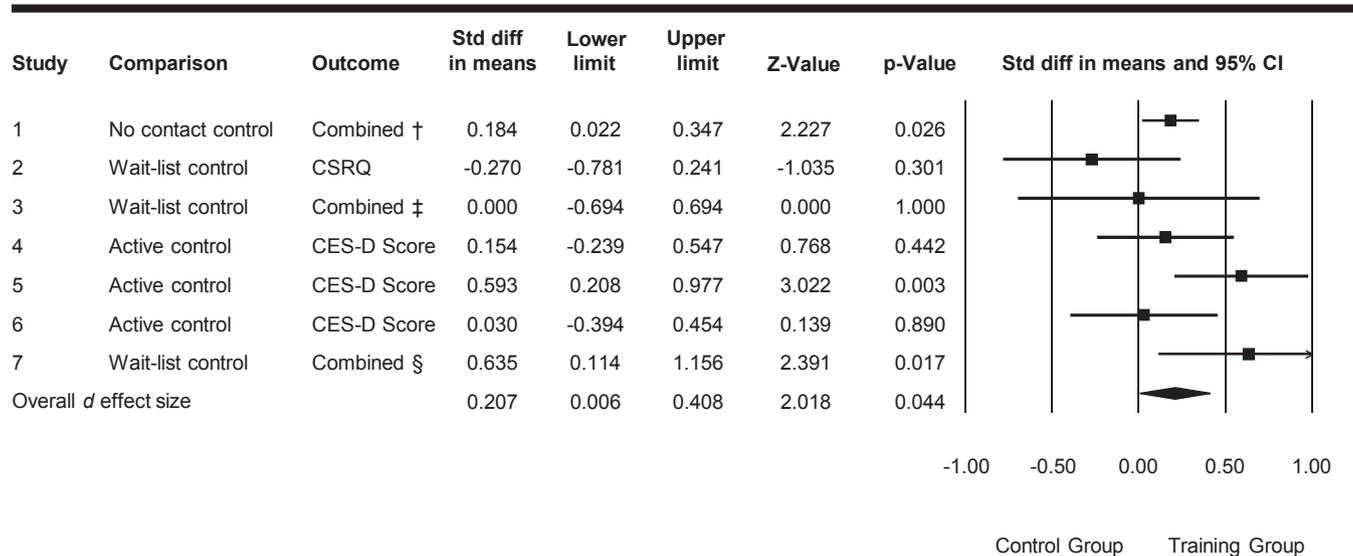
At the same time, the relevance of the theoretical debates to the translation of applied research is debatable. The present results further demonstrate that UFOV training transfers to real-world benefits including improved IADL, reduced adverse driving events, and better well-being. From an applied perspective, it does not matter if UFOV training improved an underlying ability, or a skill, or performance, as long as training resulted in a clinically meaningful effect that is relevant to enhancing an individual's everyday life. The translation of training to improve the functional health and well-being of older adults is most important.

What is relevant to the debate over the value of cognitive training is the clinical meaningfulness of known effects (Kazdin and Nock, 2003). Some may argue that UFOV training results are limited due to small effect sizes. Although the observed effect sizes of transfer of UFOV training to IADL and well-being are small, as conventionally defined by Cohen, this does not mean that the effects are not clinically meaningful. Cognitive training studies in particular, and behavioral interventions overall, are known to generally have small effect sizes. Meta-analysis indicates that the effect sizes for physical exercise to improve overall



Note. ¹Ball et al., 2010 (N=908), Ross et al., 2015 (N=1806), Ross et al., 2017 (N=336); ²Edwards et al., 2009 (N=500); ³Roenker et al. 2003 (N=95), averaged across post-test and 18 months; †Combined = driving cessation and at-fault crashes averaged across three to ten years.

Fig. 15. Forest Plot for Useful Field of View Training Effects on Adverse Driving Events.



Note. ¹Wolinsky, Unverzagt, Smith, Jones, Stoddard, et al., 2006 (N=1804); Wolinsky, Unverzagt, Smith, Jones, Wright, et al., 2006 (N=2147); Wolinsky, Mahncke, Kosinski, et al., 2009 (N=1804); Wolinsky, Mahncke, Vander Weg, Martin, Unverzagt, Ball, Jones, et al., 2009 (N=1606); Wolinsky et al., 2010 (N=1534), averaged across 1, 2, 3, and 5 years; ²Edwards et al., 2015 (N=60); ³Edwards et al., 2013 (N=87); ⁴Wolinsky et al. 2015 (N=330) at-home training; ⁵Wolinsky et al., 2015 (N=286) on-site training with boosters; ⁶Wolinsky et al., 2015 (N=305) on-site training; ⁷Von Ah et al. 2012 (N=82); CES-D = Center for Epidemiological Studies Depression Scale; CSRQ = Cognitive Self-Report Questionnaire; †Combined outcome = self-rated health, health-related quality of life, powerful others locus of control, internal locus of control, and chance locus of control, CES-D, depression onset, depression recovery; ‡Combined outcome = CSRQ and CES-D; §CES-D, SF-36 mental health subscale, Quality of Life for Cancer Survivors scale, Functional Assessment of Cancer scale with subscales assessing cognition and fatigue, Spielberger State-Trait Anxiety Inventory Scale.

Fig. 16. Forest Plot for Useful Field of View Training on Well-being.

cognition are equivalent to process-based cognitive training (Hindin and Zelinski, 2012), yet the former is more highly recommended and accepted. Similarly, meta-analysis on the effect sizes of commonly prescribed medications for dementia such as cholinesterase inhibitors and memantine also indicate small effects (Parminder et al., 2008). Small effect sizes can be just as, or even more, clinically meaningful than large effect sizes (Kazdin and Nock, 2003). A clinically meaningful effect size is subjectively defined by individuals and clinicians (Kazdin and Nock, 2003). This issue may represent yet another paradigm shift, particularly for clinical research. The Patient-Centered Outcomes Research Institute and movement highlight the need for research to focus on outcomes that are meaningful to the patient and require inclusion of subjective ratings (Selby, 2013). Meanwhile, some psychologists continue to ignore or dismiss enhanced subjective outcomes from cognitive training research (e.g., Simons et al., 2016).

Experts concluded that treatments demonstrating a clear benefit over existing treatments, which also improve functional ability and quality of life, are likely to be clinically meaningful (Keefe et al., 2013). UFOV training has shown greater benefits when directly compared to other cognitive interventions (Ball et al., 2002; Ross et al., 2015) or cognitive simulation (Edwards et al., 2009b, 2005b; Wadley et al., 2006; Wolinsky et al., 2015), and UFOV training shows lasting benefits resulting in improved driving safety as compared to driver- simulator and instructor training (Roemaker et al., 2003). Furthermore, UFOV training enhances quality of life across outcomes meaningful to older adults and relevant to their sustained independence.

Kraemer and Kupfer (2006) also highlight that the definition of clinically meaningful effect sizes is dependent upon the risk, cost, and burden of a particular treatment to the patients. Treatments that have low risk, low cost, and little burden can have smaller effect sizes that are still considered clinically meaningful. These are important factors to consider when evaluating effect sizes of cognitive training. The risks of

cognitive training for the participant are very low, the cost is also quite low (UFOV training costs \$8-14/month), and the burden was a mere 10 h of training in most of the studies reviewed. The present results indicate that a small investment of 10–18 h of cognitive training has enduring effects with real-world benefits. We conclude that UFOV training shows clinically-meaningful effects with great potential to enhance older adults’ lives. Given these benefits and considering that the risks of completing UFOV training are minimal and the time commitment and costs are low, UFOV training should be a recommended preventative approach for older adults to maintain functional health and well-being. Similar conclusions have been reached by other scientists who have conducted meta-analyses of cognitive training (Lampit et al., 2015).

4.3.4. The value of driving outcomes

Although the real-world functional ability of driving is significantly enhanced by UFOV training, the value of these benefits have been questioned (Simons et al., 2016). It is important to note that these results are an outcome of decades of systematic research, which first identified the UFOV test as a strong, independent predictor of driving safety among older adults (Ball and Owsley, 1993; Ball et al., 1990a, 1993, 2006, 1990b; Charman, 1997; Classen et al., 2009, 2013; Clay et al., 2005; Goode et al., 1998; Wood et al., 2012). Paired with the paradigm-shifting finding that older adults’ perceptual abilities could be improved with practice (Ball et al., 1988; Ball and Sekuler, 1986; Sekuler and Ball, 1986) and a theoretical basis (Sekuler and Blake, 1987), an obvious next step in the scientific process was to examine if UFOV training improves driving safety (Roemaker et al., 2003). Three randomized clinical trials (Ball et al., 2010; Edwards et al., 2009a, 2009b; Roemaker et al., 2003), and results of these quantitative meta-analyses confirm that UFOV training translates to improved and prolonged driving safety among older adults. Opponents to cognitive

training have attempted to diminish the value of this transfer of training in a number of ways (Simons et al., 2016). One of their assertions is that other approaches to older driver rehabilitation such as driving avoidance or education may be more effective. On the contrary, randomized clinical trials and systematic reviews show that educational programs and driving avoidance are ineffective in reducing crash risk among older adults (Bédard et al., 2008; Kua et al., 2007; Nasvadi and Vavrik, 2007; Owsley et al., 2004; Owsley et al., 1999; Ross et al., 2009). Rather, older drivers engaging in avoidance behaviors tend to crash more frequently (Ross et al., 2009). Although some interventions improve driving on-road performance (Casutt et al., 2014; Jacobs et al., 1997; Kua et al., 2007), awareness (Marottoli et al., 2007), and knowledge (Bédard et al., 2008), UFOV training is the only intervention to date shown to reduce older drivers' crashes, to our knowledge. However, critics assert that these effects were not of practical value because only crashes in which the trained driver was at-fault were reduced. It is unreasonable to expect UFOV training to prevent crashes caused by other drivers who were not trained (e.g., the trained drivers' car was hit while parked). Finally, critics have attempted to diminish the value of this transfer by pointing out that crashes are rare events. The cost of crashes in terms of dollars and even more importantly, human lives, are ignored in this critique. Of note, older drivers with poor UFOV file more costly insurance claims (Ross et al., 2011), and are 16–22 times more likely to cause a crash with injuries (Owsley et al., 1998). Further, older drivers and their passengers are more likely to be injured or killed when in car crashes as compared to other age groups, particularly from at-fault crashes (Braver and Trempel, 2004; Li et al., 2003). Given the potential severe and even mortal consequences of crashes, any degree of risk reduction is valuable. Indeed, automobile insurance companies have conducted independent field trials of UFOV training and found reduced claims and crashes are a benefit of this intervention (American Automobile Association, 2016). Finally, critics argued that prolonging older adults' driving mobility is not of value (Simons et al., 2016). This ignores a great deal of evidence on the negative consequences of driving cessation for older adults including: higher rates of nursing home admissions, increased depression and social isolation, less access to healthcare, greater declines in health, and increased mortality, as a few examples (Edwards et al., 2009c, 2009d; Elliott et al., 2014; Freeman et al., 2006; Marottoli et al., 2000, 1997). We acknowledge as a limitation that the N_f s for driving mobility outcomes was small and more research is warranted. In conclusion, we argue that even small effects of prolonging safe driving mobility are of great, perhaps inestimable, value.

4.3.5. Multiple statistical corrections

Not adjusting for multiple correction is a valid concern. At the same time, the appropriate use of statistical corrections is debated within and across fields, and this is not an issue unique to cognitive training studies. The other side of this debate is that adjusting for multiple comparisons is not always necessary (Rothman, 1990), and that replication of results across studies (as shown here) is sufficient (Drachman, 2012). Not adjusting for multiple corrections can lead to false claims, while adjusting alpha levels for multiple comparisons increases the probability of false negatives, potentially yielding incorrect conclusions that cognitive training is not effective. Cognitive training is a low risk, low cost intervention. In such cases, less conservative statistical approaches are appropriate, particularly given that the potential benefits of cognitive training greatly outweigh the risks. The present results indicate that across multiple clinical trials, the proximal effects of UFOV training as well as the far transfer to improved IADL, reduced adverse driving events, and enhanced well-being are all significant at an alpha level of 0.001. Applying correction for multiple comparisons does not nullify the statistical significance (or clinical meaningfulness) of UFOV training effects.

5. Future research

To date, the amount of training on specific exercises needed to experience benefits is unclear. The ACTIVE study showed that transfer of UFOV training to everyday function was not evident until after at least 9 h of adaptive training sessions (Willis et al., 2006). Similarly, Kelly et al. (2014) concluded that at least 10 h of training were needed to derive benefits. This minimum amount of 10 h may apply to each cognitive training exercise if multiple exercises are included in a cognitive training program. We have not noticed participants reaching a ceiling level of performance in existing training studies. At the same time, there is a clear dose-response effect of UFOV training sessions (Ball et al., 2013). The dose-response function of training requires further investigation.

Future cognitive training studies should incorporate performance-based assessments of everyday function, focusing on outcomes that are clinically meaningful to participants and clinicians. Although UFOV training shows transfer to improved real-world outcomes, perhaps some cognitive training programs do not. Cognitive training approaches vary in effects by type and even within cognitive training type effects vary across time. For this reason, future systematic reviews and meta-analyses need to focus on individual training techniques, rather than equating different approaches of cognitive training. For example, recent meta-analyses have focused on working memory training (Au et al., 2015). Furthermore, comparative effectiveness research of different cognitive training approaches is warranted. Finally, research is needed to delineate the underlying mechanisms of efficacious training, and moderators of cognitive training gains should be further explored to examine who benefits, keeping in mind that some benefits may only emerge longitudinally (e.g., Rebok et al., 2014).

6. Conclusions

The field is at a critical juncture in which the data from cognitive training studies is challenging to existing theories and paradigms. We face a choice to either dismiss cognitive training to preserve existing theories and paradigms, or to update such paradigms to accommodate new data. Dismissing effective behavioral interventions on theoretical grounds is not beneficial to public health. Rather, the promulgation of evidence-based interventions, like UFOV training, coupled with the continued investigation of cognitive training is recommended.

Acknowledgements

Dr. Edwards previously served as a limited consultant to Posit Science, Inc. from June to August of 2007.

Results of these analyses were presented in a symposium at the 2016 annual meeting of the American Psychological Association.

We would like to thank Jasmine Alicea, Carnesha Westbrooks, and Claudia Dold for assistance in performing the literature searches.

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