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Review article

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

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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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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