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Does attention training work? A selective meta-analysis to explore the effects of attention training and moderators

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ABSTRACT

The main goals of this selective meta-analysis on the populations of ADHD, learning difficulties and typically developing individuals were (a) to determine whether attention can be improved by attention training programs, (b) to examine whether attention training effects transfer to other outcomes (i.e., academic and cognitive skills), and (c) to identify moderators of the attention training effects on attention. A meta-analysis of 15 studies with 113 effect sizes found a significant, medium-sized training effect on attention, Hedges $g = .25$, 95%CI [.02, .47] and the effects of attention training significantly transferred to non-trained tasks (academic and cognitive skills), Hedges $g = .24$, 95%CI [.01, .47]. Moderation analyses indicated that attention training is more effective for improving attention when the training is adaptive and is more effective for younger individuals and for individuals with ADHD. Also, attention training seems more effective for improving attention when it targets the orienting attention network. The implications of these findings with respect to attention training are discussed.

1. Introduction

Attention plays an important role in our daily tasks, especially learning, and is one of the most studied cognitive constructs in education and psychology. Recently, an increasing number of studies have examined the efficacy of cognitive attention training, in which the various cognitive components of attention (e.g., sustained attention, divided attention) are viewed as skills that can be improved by training (Tamm, Epstein, Peugh, Nakonezny, & Hughes, 2013). Some studies indicate that attention is malleable (e.g., Karbach & Kray, 2009; Stevens et al., 2013) even with relatively brief training (e.g., 77 min; Wass, Porayska-Pomsta, & Johnson, 2011) and that attention training effects can transfer to other skills (e.g., academic performance, Solan, Larson, Shelley-Tremblay, Ficarra, & Silverman, 2001). However, other studies do not find such training effects (e.g., Rapport, Orban, Kofler, & Friedman, 2013).

Clearly, it is important to gain a better understanding of whether boosting attention skills by means of attention training is feasible and whether the training can transfer to other untrained skills. Two meta-analytic reviews have reported on the effect of attention training (Rapport et al., 2013; Wass, Scerif, & Johnson, 2012). Rapport et al. (2013) examined the effect of cognitive training, including attention, short term memory, and "mixed executive function", specifically among children and adolescents with ADHD. Within their review, they examined 6 attention training studies each targeting orienting/alertness, vigilance/sustained attention, selective/focused attention, and/or divided attention. Rapport et al. (2013) found that these attention training studies did not significantly enhance performance on attention outcomes or other measures.

Wass et al. (2012) reviewed the relation between cognitive skills training and age. They included training studies that targeted either working memory or "mixed attention". Mixed attention referred to one or more of the following cognitive domains: sustained attention, selective attention, task switching, and inhibition. The participants in the selected studies ranged in age from 11 months to 96 years, and they included six populations: typically developing; ADHD; acquired brain injury; schizophrenia; individuals with social and emotional difficulties; other. Across a total of 37 studies (18 working memory; 19 mixed attention), Wass et al. (2012) found that cognitive training may be more effective among younger than older individuals, and this effect was stronger for working memory training than mixed attention training.

The present meta-analysis fills notable holes in the literature. Rapport et al. (2013) examined the efficacy of attention training among children and adolescents with ADHD, but they did not include studies that examined non-ADHD populations. Wass et al. (2012) examined the relation between cognitive training and age across six different populations, but they did not address the basic research question of whether attention training is an effective means of improving attention. In the current meta-analysis, we tried to expand the findings from these previous reviews by exploring the effects of attention

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training. Specifically, we tried to aggregate studies that employed attention training to improve performance on attention, and non-trained cognitive and academic skills to gain insight into if, when, how, and for whom attention training should be applied in educational settings. We intentionally excluded studies that trained emotional attention for anxiety reduction or other therapeutic effects (e.g., Donald, Abbott, & Smith, 2014; Hakamata et al., 2010; Mulkens, Bogels, de Jong, & Louwers, 2001), and we only included studies on typically developing individuals, individuals with ADHD, and individuals with learning difficulties as to understand the relative effectiveness across these groups.

Furthermore, we investigated factors that might moderate the training effects on attention. Specifically, we examined moderators of theoretical interests such as age and sample type, and moderators of methodological interests such as the type of attention the training targeted, control group type, characteristics of training implementation, and outcome measure objectivity. Our goal was not only to determine whether attention training is effective, but also to gain insight into the variables that should be considered in order to maximize effectiveness. This information could potentially be applied to design and implement attention training programs for use in educational settings aimed at improving academic outcomes. In the following sections, we described the theoretical framework of attention we adopted and the moderators we investigated in the current review.

1.1. Attention networks

Attention is defined as the appropriate allocation of processing resources to relevant stimuli and is thought to comprise several sub-processes (Coull, 1998). Attention training usually targets one (but sometimes more) of these sub-processes. Whereas previous reviews on attention training have collapsed across studies regardless of the specific aspect of attention trained (Rapport et al., 2013; Wass et al., 2012), the present review compared the efficacy of targeting a specific attentional network: alerting, orienting, or executive attention.

Beginning with James in 1890, a number of attention theorists have proposed that attentional processes are multi-componential (e.g., Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Posner & Boies, 1971) and that these processes are independent, yet cooperate and work closely together. Posner and colleagues suggest three attention networks: (1) alerting, involved in acquiring and maintaining readiness to react, (2) orienting, involved in orienting attention to sensory stimuli, and (3) executive attention, involved in conflict resolution (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Posner & Petersen, 1990). Behavioral data suggest distinctions among these three networks (Callejas, Lupiáñez, & Tudela, 2004; Fan, McCandliss, Sommer, Raz, & Posner, 2002). For example, data from the Attention Network Test (ANT) shows that among adults (Fan et al., 2002) and children (Rueda et al., 2004), different tasks evoke unique responses from the three networks. In addition, evidence from stroke patients suggests a triple dissociation of the attention networks according to the lesion location (Rinne et al., 2013). The triangulation of evidence from behavioral, neurobiological, and genetic data provides strong support for this three-part framework (see Raz & Buhle, 2006, for a review). Although the attention networks can be individually assessed and measured, they are notable because their primary purpose is to influence the processing of other neural networks (Rothbart & Posner, 2006).

1.1.1. Alerting

Alerting is the ability to prepare for and maintain readiness to make a response (Posner & Petersen, 1990). The alerting network encompasses sustained attention, vigilance, and alertness and allows the individual to maintain response readiness in anticipation of an impending stimulus (Raz & Buhle, 2006). The alerting network is believed to provide the platform that allows higher level attentional processes to take place; it is considered the attentional foundation upon which other attentional functions rely (Parasuraman, Warm, & See, 1998). For the purpose of this analysis, we categorized all attention trainings that focused on sustained attention, vigilance, or alertness as “alerting” tasks. For example, Rabiner, Murray, Skinner, and Malone (2010) used an adaptive computerized training that included a number of exercises that targeted sustained attention. In one exercise participants were asked to press the space bar every time a particular symbol appeared on the screen.

1.1.2. Orienting

A second attentional network proposed by Posner and colleagues involves selectively attending to one or two items out of many candidate inputs (Posner & Petersen, 1990) and can also involve disengaging attention from one stimulus and shifting it to another stimulus (Mezzacappa, 2004). Thus orienting enables the selection of specific targets among multiple stimuli. One method of manipulating the orienting response is to present a cue that indicates a point in space where the participant should attend, thereby providing a basis for the person to direct attention to the cued location either overtly (i.e., by moving the eyes to directly fixate upon the target) or covertly (i.e., shifting attention to a spatial location without any eye movement; Posner, 1980). The orienting response is often measured by subtracting the reaction time to respond to a target following an orienting cue (i.e., a cue that causes people to attend to a particular spatial location) toward the impending target, from trials in which no orienting cue is given. This estimates the individual's ability to orient their attention to a particular location.

1.1.3. Executive attention

The third network in Posner and colleagues' framework is executive attention, which includes the control of goal directed behavior, target detection, error detection, conflict resolution, and inhibition of automatic responses (Posner & Petersen, 1990). Executive attention is also commonly referred to as executive control, supervisory, selective, conflict resolution, and focused attention (Raz & Buhle, 2006). Tasks that require planning or decision making; error detection; regulation of thoughts and emotions; and performing novel responses or resisting the performance of habituated ones are all considered tasks of executive attention. Classic tasks used to measure executive attention typically involve a conflict between the stimulus and the response. One example is the Stroop task in which the names of colors are presented in a consistent font color (e.g., the word *red* written in red font) in some trials and an inconsistent font color (e.g., the word *red* written in blue font) in other trials. The task requires participants to name the font color, ignoring the written word. Executive attention is typically measured by subtracting the reaction time to respond to consistent trials from inconsistent trials.

1.2. Training attention networks

Because the three attention networks serve unique functions in the attention system, it seems plausible that attention training might have variable impact, depending on the attention network targeted. Raz and Buhle (2006) suggest that the alerting network might potentiate the efficiency of the other networks. Based on this idea, training the alerting network might prove more advantageous than training either the orienting or executive attention networks; strengthening the alerting network might lay a requisite foundation upon which higher level attention skills might be built. There is evidence for such interactions among the attention networks (Callejas, Lupiáñez, Funes, & Tudela, 2005; Fuentes & Campoy, 2008; Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014). For example, Pozuelos et al. (2014) examined the development of the attention networks among children age 6–12 and found that alerting cues were associated with enhanced orienting ability. Alerting and orienting cues were associated with improved performance on an executive attention task.