Can Attention Itself Be Trained?
Attention Training for Children At-Risk for ADHD

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A. What is Attention Training?

Attention Training (ATT) is based on the concept that efficiency increases after repetitive practice of specific cognitive operations of attention (Posner & Raichle, 1994) because practice produces adaptations in the underlying neuroanatomical networks linked to these processes (Kerns, Eso, & Thompson, 1999). This concept has origins in the field of cognitive rehabilitation where Attention Process Training (APT), using tasks such as listening for descending number sequences, shifting set, and visual cancellation, has been used to activate and train sustained, alternating, and divided attention (Sohlberg & Mateer, 1989). It should be noted that the term “Attention Training” has also been used to refer to different approaches, including 1) neurofeedback or biofeedback, 2) electronic equipment designed to give the child feedback when he/she is off task, and 3) cognitive training techniques, which involve training the child to self-talk to keep themselves on task and paying attention. We do not review these approaches in this chapter. Instead, we specifically refer to ATT methodologies as those using adaptive tasks specific to attentional functions thought to have certain corresponding neural bases which are changed through repetition and practice.

Several randomized controlled trials have been conducted to investigate the efficacy of ATT in different populations, including traumatic brain injury and stroke. The majority of these studies report positive findings and demonstrate transfer of improvements on untrained assays of attention components such as sustained attention and executive function (Ethier, Braun, & Baribeau, 1989; Finlayson, Alfano, &

Sullivan, 1987; Gray & Robertson, 1989; Mateer & Mapou, 1996; Penkman, 2004; Sohlberg & Mateer, 1987; Thompson & Kerns, 1995).

One criticism that has been levied against ATT methodologies is that they have not been based on a theoretical model or framework of attention (Mateer & Mapou, 1996). Some ATT approaches have focused on training sustained attention, while others focus on alternating or divided attention or executive conflict, making it difficult to compare results. Posner and colleagues have suggested a framework by which to understand attention based on neuroanatomical and neuroimaging evidence (Posner & Raichle, 1994). This model suggests that attention includes three major functions: alerting, orienting, and executive control, associated with specified neuroanatomical networks (i.e., different networks of interconnected brain areas). The alerting network is involved in establishing a vigilant state and maintaining readiness to react. Imaging studies show that the alerting network depends largely on frontal and parietal areas of the right hemisphere (Coull, Frith, Frackowiak, & Grasby, 1996; Posner & Petersen, 1990). Orienting involves selectively focusing on one or two items out of many candidate inputs. The orienting network utilizes superior and inferior parts of the parietal lobe in conjunction with frontal and subcortical structures related to eye movements (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000). The executive control network has been related to the control of goal directed behavior, target detection, error detection, conflict resolution and inhibition of automatic responses. The executive control network involves frontal areas including the anterior cingulate and lateral prefrontal cortex (Bush, Luu, & Posner, 2000). Each of these neuroanatomical networks appears to undergo intense post-natal development (Ruff & Rothbart, 1996). Individuals with ADHD tend to show specific deficits in these functions, especially in alerting and executive control (Swanson, Posner et al., 1998).

Efforts to develop an assessment measure of these three functions has resulted in the Attention Network Test (ANT) with versions for adults (Fan, McCandliss, Sommer, Raz, & Posner, 2002), school-aged children (Rueda et al., 2004), and preschool children (CUIDAR, described later in the chapter). The

ANT task is a combination of a cued reaction time and flanker task (Fan et al., 2002). Studies suggest that performance on the ANT task follows a roughly normal distribution (Fan, Yanhong, Fossella, & Posner, 2001), and that performance is stable within normal adult subjects across a wide age range with no gender differences. It has also been shown that practice or previous experience has little impact on the attentional measures although overall reaction time is somewhat reduced (Fan et al., 2001), making it a good candidate as an outcome measure for ATT of alerting, orienting, and executive control.

Posner et al (Posner, 2002) proposed testing the utility of the idea that implementing ATT early in development may actually enhance attention and executive control networks. Neuropsychological studies suggest extensive development of attention and executive control functions between the ages of three and five, which correlate with developments in brain structure and function. Although the neurological basis of the effect of ATT is not yet understood, evoked potential measures and fMRI evidence suggest that ATT is impacting brain function (Mateer & Mapou, 1996; Olesen, Westerberg, & Klingberg, 2004). Implementing ATT with preschool-aged children may have a long term impact on the functional development of these systems. Further, implementing ATT with children at risk for the development of attention and behavior problems may prevent or arrest impairments of attention. Evidence suggests that computerized game-like tasks can be utilized to assess and/or train attentional functions in preschool-aged children (Berger, Jones, Rothbart, & Posner, 2000). Thus, researchers have adapted ATT materials to be developmentally appropriate for both typically developing and "at-risk" preschoolers.

B. Applications of Attention Training for ADHD Populations

Since Attention-Deficit/Hyperactivity Disorder (ADHD) is by its very nature a disorder of attention, ATT has been considered as a possible non-pharmacological alternative to treatment with stimulant medication. There are few studies investigating the utility of ATT in the ADHD population, however. Williams (Williams, 1989) utilized adult-based attention training materials with a group of six ADHD children. Forty hours of ATT yielded significant improvements in pre-post measures of attention. In a somewhat larger study (n = 33) by the same researcher, latency-aged children (8 to 12 years of age) diagnosed with ADHD were tested before and after an 18 week period, during which children were divided into a no-treatment control (NTC) group and an treatment group that received 36 sessions of ATT using materials augmented with problem solving activities developed for adults. Significant treatment group effects were reported for measures of both sustained and executive attention. A cancellation task that involved discriminating between several potential targets showed a 32% improvement for the ATT group vs. an 8% increase for the NTC group. An auditory discrimination target counting task showed a 56% ATT improvement vs. an 18% improvement for the NTC group. These results represent an average treatment group and pre-post assessment effect size of 1.01. Despite the lack of age-appropriate materials, their findings suggest that ATT shows promise as form of treatment for children diagnosed with ADHD.

Thomson and colleagues (Thomson, Seidenstrang, Kerns, Sohlberg, & Mateer, 1984) recognized the need to adapt attention assessment and training materials to the specific needs of children in an age-appropriate fashion. Kerns, Eso, and Thompson (Kerns et al., 1999) used child-appropriate adaptations of the adult Attention Process Training (APT) materials (Sohlberg & Mateer, 1989) and conducted a randomized active treatment control study of the effects of training sustained and executive attention skills in ADHD children (7 to 11 years of age; n=14). Half the subjects were assigned to APT for 16, 30-minute sessions per week over 8 weeks, and half were assigned to a Video Game Control (VGC) group that was assigned to play age-appropriate videogames with social praise from the experimenters for an equivalent amount of time. On a measure of sustained attention (Underlining Boxes test) the APT group improved by 32% whereas the VGC group improved only 6%, and on a measure of effortful processing (a Math Efficiency measure based on the number of age-appropriate problems completed within a fixed time), the APT group showed a 55% improvement compared to 20% for the VGC group. At the level of generalization, the APT group showed a greater reduction in teacher ratings of ADHD symptoms than the VGC group, but this difference was only marginally significant ($p<.066$). At the cognitive level, this study demonstrated significant treatment-specific benefits of APT in tasks related to sustained attention and executive attention measures.

Klingberg et al (Klingberg, Forssberg, & Westerberg, 2002) developed a version of ATT with a central focus on non-verbal working memory skills. Their study evaluated the impact of 25, 30-minute sessions of ATT on a group of children with ADHD (n=14, 11 +/- 2.5 years of age). The treatment was delivered by computer in an adaptive fashion (i.e., each trial was dynamically adjusted to each child's ability to preserve high success and an element of challenge). In a randomized controlled study in which the assessment team was blind to assignment to "high" dose (experimental) or "low" dose (control) groups, the experimental group (n=7) produced significantly greater gains on cognitive measures of sustained and executive attention reflecting performance on visual-spatial working memory, digit span, and Stroop tasks. Also, the treatment effects were significant for a measure of restlessness: the number of head movements was reduced by 74% in the experimental group, yet increased by 8% in the control group (an effect size of 1.75), which is comparable to the 62% reduction in head movement typically reported following 0.4 mg/kg methylphenidate in a similar paradigm and population (Teicher et al., 2000). However, treatment effects on reaction time latency or variability did not reach statistical significance. An imaging study showed that the working memory treatment was effective in improving activation of brain areas related to working memory (Olesen et al., 2004).

Shalev et al (Shalev, Tsal, & Mevorach, 2004) conducted a study of a version of ATT designed to adaptively challenge children in tasks that required sustained attention, selective attention, spatial orienting, resolving conflict, and dual task management. The study included children diagnosed with ADHD from 6 to 13 years of age randomly assigned to 16 sessions of ATT using the Progressive Attentional Training System (n=24) versus a video game control (VGC; n=17). Performance on an effortful, timed, passage copying task demonstrated a 48.7% improvement for the ATT group in the number of words copied, whereas the VGC group demonstrated a non-significant increase of 1.8%. Most strikingly, parental rating scores for the ATT group were reduced for ratings of inattention (by 23%) and hyperactivity (by 19%), but no significant reduction was found for the VGC group on these pre-post measures assessed by raters blind to treatment condition.

Taken together, these studies provide significant support for the notion that adaptive training of executive function skills and sustained attention skills may positively impact the developing attention skills of elementary school aged children with ADHD, and such increases may, under some circumstances, generalize to ecologically valid assays of real-world effortful task performance and expression of ADHD symptoms.

C. Attention Training for Preschool Children

Posner, Rothbart, and colleagues have recently completed a three-year project funded by the McDonnell Foundation to investigate the impact of attention training on typically developing preschool children (Posner, 2004; Rueda, McCandliss, Rothbart, & Posner, in preparation). ATT activities were adapted from a non-human primate study by Rumbaugh and Washburn (Rumbaugh & Washburn, 1995) that demonstrated significant gains in attentional abilities of primates following adaptive (i.e., progressive increases in the amount of challenge on sustained attention and other attention skills) computer-based activities. Adapting these procedures for use with preschool children involved creating animated animal characters, and game-like motivational schemes for a battery of interactive exercises. For example, one activity that required planning and maintaining information over a delay period was re-conceptualized as a game of tag between a duck and a cat character, in which the child controlled the cat character, and the duck character would present challenges, such as disappearing into a pond in a way that required the child to remember the duck's path, and anticipate and plan for the duck's return. Difficulty was adapted by manipulating the duration of the delay and the relative speed of the two characters in the 'tag' game.

To evaluate the impact of these activities on typically developing preschoolers, Rueda and colleagues (Rueda et al., 2004) conducted a randomized controlled trial with two groups of children aged 4 to 5 years old. The study contrasted the impact of 5 days of ATT (n=24) with a randomly assigned control group (n=24) that watched videos with an interactive component. Following training, children in the ATT group showed more adult-like performance in the conflict network of the ANT task than the control children and this performance was also reflected in an event related potentials component associated with the ability to resolve conflict. In addition, the ATT group showed a significantly greater pre-post change in a preschool analog of the Raven's progressive matrices test, the Kaufman Brief Intelligence Test (K-BIT) nonverbal IQ score (Kaufman & Kaufman, 1990), when compared to controls.

This preliminary research demonstrates that computer-based ATT activities developed for adult and school-aged children can be adapted for use with preschool children. It also provides support for the hypothesis that such training can influence relevant behavior, generalize beyond the training tasks, and influence the underlying attentional network. Thus, it is plausible that ATT might be utilized as a possible intervention for preschoolers with attention problems.

Dowsett and Livesey demonstrated that some forms of ATT might be effectively adapted for preschool children at risk for attention difficulties (Dowsett & Livesey, 2000). They studied 47 children (age 3 to 5) that had significant difficulties inhibiting responses during an age-appropriate Go/NoGo task. Children receiving three sessions of executive function training (dimensional card sort task, change task) demonstrated significant improvements on the Go/NoGo task, in contrast to both a no-intervention control group and a practice control group that received no training but three sessions of practice on the same Go/NoGo task.

D. Attention Training and the CUIDAR Program

New developments from the cognitive neurosciences about brain plasticity (see (Posner, 2001) set the stage for a collaboration of investigators at UCI and the Sackler Institute to investigate ATT, which challenged the consensus views (see Swanson, Sergeant et al., 1998). The traditional view has been that ADHD symptoms are due to fixed biological differences (e.g., a dopamine deficit) and that effective treatments (e.g., pharmacological intervention with stimulant medication or even behavioral interventions with token systems) offer "symptomatic relief" but have no carryover benefits and thus must be used chronically.

A new hypothesis purports that ADHD symptoms may be due to inefficient neural networks that could be strengthened during early development by specific experiences delivered by adaptive training (McCandliss & Noble, 2003). A fortunate collaboration between clinicians and scientists at the University of California, Child Development Center, and the Children's Hospital of Orange County (CHOC) provided an opportunity to test the cognitive neuroscience vision of ATT in preschool children at risk for ADHD. In 2000, California Proposition 10 imposed a statewide tax on tobacco products, with the proceeds specifically designated to fund service delivery programs to enhance school readiness. In 2001, a group of clinicians from UCI and CHOC proposed a service delivery program for preschool children at risk for ADHD, which was labeled the CHOC-UCI Initiative for the Development of Attention and Readiness (CUIDAR), funded by the Children and Families Commission of Orange County.

1. Parent Groups

CUIDAR is based on application of an early intervention and prevention model for preschoolers with behavior problems suggesting risk for later diagnosis of ADHD. The primary intervention is based on a once-a-week, 10-session Community Parent Education (COPE) program, which is supplemented by concurrent social skills/child care for the preschool children. After completion of the COPE program, an optional medical clinic evaluation of ADHD is provided. Thus, CUIDAR provides service via a psychosocial intervention (COPE) before diagnosis and consideration of pharmacological intervention. Over the past 3 years, this approach has been used with over 1500 families, and has been well-regarded by participating families, pediatricians, and schools. The program has been especially well received by the Spanish-speaking Latino/Hispanic population, a group that underutilizes behavioral health services. A discussion of issues related to designing and implementing the CUIDAR model is provided by Tamm et al (Tamm et al., submitted). Preliminary information from the start-up experience (rather than a controlled clinical trial), show that parents report overwhelming satisfaction with the program, significant gains in parenting skills, and a reduction in child behavior problems.

Parent education was selected as the main method of intervention because it has a long history of demonstrated efficacy in reducing child behavior problems (Barkley, 1987; Endo, 1991; R. Forehand, & McMahon, R.J., 1981; R. Forehand, Rogers, McMahon, Wells, & Griest, 1981; Patterson, 1985; Webster-Stratton, 1981). This psychosocial intervention is also more acceptable to parents and professionals than pharmacological intervention, in part due to the weaker evidence base for the efficacy of medication at this age, and the potential of greater side effects of medication in young children (Endo, 1991; R. Forehand et al., 1981; Webster-Stratton, 1981). While many different approaches to teaching parenting skills have been shown to be effective, most approaches teach a similar curriculum based on behavior modification and social learning principles.

In the COPE model (Cunningham, 1998; Cunningham, Bremner, & Boyle, 1995) parents participate in 10 week program in which parenting skills are taught in a unique, interactive approach to a group of 20-25 parents. The large group is subdivided by the COPE facilitator into small discussion groups of 4-5 parents, and these groups are systematically led through the COPE curriculum that focuses on teaching the following parenting strategies: 1) Praise and Attending, 2) Rewards, 3) Planned Ignoring, 4) Transitional Warnings, 5) When-Then Statements, 6) Planning Ahead, 7) Point Systems, 8) Time Out, 9) Time Out from Reinforcement - Loss of Privileges, and 10) Problem Solving. A primary feature of each COPE session is watching a videotaped vignette of a parenting error related to a topic of the curriculum, followed by a discussion within the small groups to identify the error and to offer suggestion for more appropriate parent-child interaction in that context. The COPE facilitator uses the group-generated solutions (1) to model appropriate parent behavior, (2) to demonstrate situations in which the strategies could be applied, (3) to practice in role playing exercises, and 4) to propose homework for home implementation of the strategy before the next session.

2. Child Groups

The CUIDAR program provides a social skills intervention for children while their parents participate in the evening COPE parenting groups. The child groups follow a specific structure with a focus on prosocial behaviors. Components of the group structure include: 1) settling activity (story/coloring), 2) circle time (games/songs), 3) introduction of a social skill (using puppets), 4) role play of social skill (also using puppets), 5) activity time, 6) snack time, 7) movie. Throughout, a reward-based point system is used to promote positive behavior. The social skills covered in the 10-week program include following the rules of the “red sign” (observing a “red sign” for silence or required hand-raising to speak), listening and participating, ignoring, sharing, saying nice things, “calm body”, and helping others. Debriefing with an experienced COPE facilitator occurs after each group to facilitate communication between the childcare/social skills providers and group leaders, and to allow problem solving for managing more difficult children.

3. ATT in CUIDAR

CUIDAR delivers services annually to about 700 families with preschool children at risk for ADHD (see www.CUIDAR.net). This provided an infrastructure to work directly with the children in these child care groups (while their parents attend the traditional COPE parent training groups) and created an opportunity to develop materials for ATT. Our goal was to develop and refine ATT materials to make the “games” appropriate for preschool children, and eventually to test the hypothesis that neural networks of attention (i.e., alerting and executive control as defined by Posner) can be strengthened by targeted adaptive training (as proposed by McCandliss for an intervention for children with reading disorders (McCandliss & Noble, 2003). The Sackler Institute and the Orange County Proposition 10 Commission provided start-up funding to adapt the materials initially developed for ATT in normal toddlers (Posner,

2004) for use with the preschool children at risk for ADHD, and a grant from the National Institute of Child Health and Development (NICHD) provided funds to conduct a pilot project with the CUIDAR families. Subsequent NIH applications have not been well received, perhaps due to the perception that this approach to implement and evaluate a program to prevent or “cure” ADHD is too radical.

The CUIDAR team focused on modifying the ANT task to be appropriate for preschoolers, since their performance was at approximately chance levels on the school-aged ANT (Rueda et al., 2004). A preschool-appropriate ANT version was developed that assesses alerting, orienting, and executive control, and that has good test-retest reliability. This allows the ANT to be employed as a “probe” task of functioning levels of the attentional network components.

As part of an integrated development plan to create a more direct link between targeted cognitive skills and ATT modules, our team designed new training tasks to impact Alerting and Executive Control. We created prototype versions of computer applications to reinforce and challenge preschoolers’ ability to sustain attention and resolve conflict.

Alerting: The Alerting activity involves a simple goal of attempting to wait and remain in a ready-to-respond state for an extended period of time, in order to rapidly respond to an infrequent and very brief event. In adapting this paradigm for children we created a “fly-catching” character, “HippityHop, the frog”. Children are instructed to help “HippityHop” by pressing the space bar to catch as many flies as fast as they can from a jar, but they must also follow 2 rules; 1) The button can only be pressed when the flies exit the jar, 2) The child must wait for the fly despite an auditory cue (buzzing) on some trials. Children are told that in some trials they will hear a buzz before the fly exits the jar but they are still to withhold their response until after the fly exits the jar. The game is adaptive in that the “catch” time changes to maintain a success rate of 50% for the uncued (non-buzzing) flies. It also slowly lengthens the wait time as children successfully catch the flies at a higher rate.

Executive Control: Similar adaptations and programming were used to produce a conflict resolution task based on the Dimensional Change Control Task (DCCT) paradigm (Zelazo, Frye, & Rapus, 1996). The DCCT paradigm was used to design a preschooler's game, using a character called Monster Zoo Keeper whose task it is to feed the monsters. On each trial the child is given an object and must decide which of two monsters should eat it, a truck eating monster that likes red things, or a flower eating monster that likes blue things. The rules whether the monsters are hungry for colors or hungry for shapes vary (i.e., during the day, the monsters are hungry for colors, and during the evening for shapes). Adaptive algorithms adjust the frequency of the rule change and the number of items that pose a direct conflict between the stated rule and recently reinforced, but currently inappropriate, decision responses.

We performed a pilot study to investigate the feasibility of implementing a randomized clinical trial with children of parents participating in the CUIDAR COPE groups, as well as to test the feasibility of using the initial modules we developed for our version of ATT and a control task. We screened commercial videogames from the Children's Software Review database (www.childrenssoftware.com) which reviews over 2500 video games, and chose Atari's "Tonka Firefighter" as an appropriate VGC example for comparison to ATT (e.g., "Hippity Hop" frog game and monster zoo game). In the Tonka Firefighter game, children play the role of a firefighter and help save the day by choosing and controlling a vehicle such as a fire truck, chopper, pump truck, or fire dozer. Children chose from a variety of activities such as saving stranded kittens, putting out blazing fires, cleaning up parks, and creating a fireworks show. Children were randomly assigned to an ATT group (n=14, 5 sessions with the Alerting task) or a VGC group (n=13, 5 sessions with the Tonka Firefighter game). The preschool version of the ANT task was administered pre and post.

The outcome of our initial feasibility study confirmed our experience and those of others of the benefits of ATT over VCG, and demonstrated that our ATT intervention in preschool children results in improvements after just 5 sessions that are about the same magnitude as those reported in the literature on elementary-school aged children with ADHD. The results of our initial pilot study will be presented in a later publication by our group. We utilized our experience with the feasibility study to modify and refine the prototypes of the Alerting and Executive Control tasks. For example, additional "skins" and related "cover-stories" were developed so that the key task elements and paradigm are preserved, but the surface level of the task modified to be interesting for a child performing the task several times.

We are now conducting a randomized clinical trial to investigate the specificity of the Alerting and Executive Control tasks. Preschool children in the CUIDAR childcare groups have been randomly assigned to an Alerting Training (AT) group (n=9) or an Executive Control Training (EC) group (n=8). Each group is receiving 6 ATT sessions with the Alerting task or the Executive Control task, respectively. The preschool ANT task and the KBIT administered pre and post will serve as primary outcome measures, and we anticipate that the ANT Alerting scores will be improved for the AT group and the ANT Executive Control scores will be improved for the EC group. We are also exploring whether these tasks can be adapted upwards to be age appropriate for a school-aged population (ages 7 to 12), and utilized as a treatment for ADHD.

E. Can Attention Be Trained?

Although far from conclusive, it does appear that attention can be trained. Further, it appears that ATT can be adapted successfully for preschoolers, and has promising evidence as an intervention for children at-risk for or diagnosed with ADHD. Future studies should examine the specificity of ATT tasks, utilize imaging techniques to explore the impact of ATT on brain function, and investigate whether attentional gains are generalizable to other settings.

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