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The Efficacy of Computerized Cognitive Training in Adults With ADHD: A Randomized Controlled Trial

Adi Stern[1,2], Elad Malik[2], Yehuda Pollak[3,4], Omer Bonne[2], and Adina Maeir[1]

Abstract

Objective: This is a randomized control trial examining the efficiency of computerized cognitive training (CCT) for adults with ADHD, comparing two training conditions with graded levels of executive cognitive demands. **Method:** Adults with ADHD (n = 60) were randomized into study (n = 34) and control (n = 26) groups. Training was conducted with the computerized AttenFocus program. Control group received a simple, non-hierarchical version with less executive demands. **Results:** Significant positive changes in symptoms ratings, ecological measures of executive functions, and occupational performance were found in both groups. No significant changes were found in variables of neurocognitive performance battery and quality of life. No significant time by group interaction effects were found. **Conclusion:** No benefits of the intervention were found relative to the control. Lack of interaction effects may be due to insufficient power, non-specific cognitive training or placebo effects. Results demonstrate some positive findings for general CCT, yet do not support the inclusion of specific higher level executive training. *(J. of Att. Dis. XXXX; XX(X) XX-XX)*

Keywords

Adult ADHD, executive function (EF), computerized cognitive training (CCT), ecological measures

Introduction

ADHD is a neurodevelopmental disorder that is characterized by a pattern of behavior, present in multiple settings (e.g., school and home), that can result in performance deficits in social, educational, or work settings. Symptoms of the disorder are divided into two categories of inattention and hyperactivity and impulsivity (*Diagnostic and Statistical Manual of Mental Disorders*, 5th ed.; *DSM-5*; American Psychiatric Association [APA], 2013). Long-term controlled follow-up studies have shown that the disorder persists in a sizable number of adults who were diagnosed as having ADHD in childhood, and the estimated prevalence of adult ADHD is between 2.5% and 4% of adults worldwide (APA, 2013; Fayyad et al., 2007; Kessler et al., 2006; Wilens, Faraone, & Biederman, 2004). Furthermore, the definition of ADHD has been updated in *DSM-5* (APA, 2013) to more accurately characterize the experience of affected adults. This revision is based on nearly two decades of research showing that ADHD, although a disorder that begins in childhood, can continue through adulthood (APA, 2013).

ADHD is now increasingly recognized as a developmental impairment that involves deficient executive functions (EFs; Brown, 2008, 2013). The term *executive function* refers to a set of regulatory processes necessary for selecting, initiating, implementing, and overseeing thought, emotion, behavior, and certain facets of motor and sensory functions (Roth, Isquith, & Gioia, 2005). EFs enable goal-directed behavior and play a critical role for all individuals as they manage multiple tasks of daily life. EFs comprise inhibition, initiation, sustaining effort, shifting cognitive set, working memory, emotional regulation, planning, organizing, and monitoring (Barkley, 2012; Brown, 2008, 2013; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Lezak, Howieson, Loring, Hannay, & Fischer, 2004; Nigg et al., 2005; Roth & Saykin, 2004). Converging evidence points to prominent disturbances in a wide range of EFs in children and adults with ADHD that impedes their daily functioning and the quality of life (Biederman et al., 2006; Biederman et al., 2007; Brown, 2013; Ek & Isaksson, 2013; Nigg et al., 2005; Roth & Saykin, 2004).

[1]School of Occupational Therapy, Hadassah and Hebrew University of Jerusalem, Israel
[2]Department of Psychiatry, Hadassah Medical Center, Jerusalem, Israel
[3]Shaare Zedek Medical Center, Jerusalem, Israel
[4]Hebrew University of Jerusalem, Israel

Corresponding Author:
Adi Stern, MSc, OTR, School of Occupational Therapy, Hadassah and Hebrew University of Jerusalem, P.O. Box 24026, Mount Scopus, Jerusalem, Israel, 91240.
Email: adi.schleyer@mail.huji.ac.il

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Adults with ADHD have problems engaging in everyday activities (Brown, Reichel, & Quinlan, 2009; Ek & Isaksson, 2013). The functional and occupational implications of living with ADHD are becoming more evident as the research on adult ADHD increases. These implications include impairments in academic, occupational, social, and emotional domains of functioning (Adler et al., 2006; Barkley & Murphy, 2010; Ek & Isaksson, 2013; Solanto, Marks, Mitchell, Wasserstein, & Kofman, 2008). In addition, adults with ADHD have been shown to be at greater risk for lower socioeconomic status, fewer years of education, lower academic achievements, lower rates of professional employment, more frequent job changes, more work difficulties, increased rates of antisocial behavior and arrests, driving violations, parenting difficulties, relationship difficulties manifested in interpersonal conflicts and higher rate of spousal separation and divorce (Adler et al., 2008; Barkley, 2002; Barkley, Murphy, & Fisher, 2008; Brod, Johnston, Able, & Swindle, 2006; Johnston, Mash, Miller, & Ninowski, 2012; Solanto et al., 2008; Wilens et al., 2004). Therefore, it is not surprising that adults with ADHD demonstrate serious impediments in their quality of life in multiple domains of well-being (Barkley, 2002; Barkley et al., 2008; Matza, Van Brunt, Cates, & Murray, 2011; Wehmeier, Schacht, & Barkley, 2010; Wilens et al., 2004). These broad and pervasive functional implications of ADHD have been shown to be uniquely affected by the cognitive executive symptoms of ADHD. Thus, deficits in EFs have been found to have a negative impact on the functional outcomes of adults with ADHD beyond that conferred by the diagnosis of ADHD alone (Biederman et al., 2006; Solanto et al., 2008). Taken together, these findings suggest that a treatment focus on the cognitive executive symptoms of ADHD may be a positive avenue for improving the daily functioning and quality of life of adults with ADHD.

Pharmacological treatment by psychostimulants, and currently also by nonstimulants, is the most common treatment for ADHD (Castle, Aubert, Verbrugge, Khalid, & Epstein, 2007; Dodson, 2005; Peterson, McDonagh, & Fu, 2008; Spencer, Biederman, & Wilens, 2004; Tcheremissine & Salazar, 2008). Overall rates of efficacy of stimulant drugs in adults in controlled studies are somewhat lower than they are with children, ranging between 25% and 78%, with the higher rates reported in studies employing higher doses (Spencer et al., 2004). Despite the substantiated evidence of pharmacological treatment for ADHD, a considerable number of adults with ADHD do not utilize this treatment due to several causes: (a) a lack of interest in using pharmacological treatment due to a variety of reasons (e.g., fear of side effects, negative believes about medication use), (b) drug side effects (Dodson, 2005; Wilens et al., 2004), and (c) a lack of responsiveness to drug treatment (Solanto et al., 2008). In addition, many patients who respond well to drug treatment do not achieve full remission of the symptoms (O'Connell, Bellgrove, Dockree, & Robertson, 2006; Solanto et al., 2008). Nevertheless, with the exception in regard to sustained attention (vigilance), evidence seems to be growing that in adults, as with children, medications do not necessarily normalize neuropsychological outcomes (Advokat, 2010). For these reasons, drug treatment alone may not be sufficient to remediate the deficits associated with ADHD, and it is important to develop additional treatment methods that could target the core neuropsychological deficits of ADHD (O'Connell et al., 2006; Rabipour & Raz, 2012; Solanto et al., 2008). Thus, the pharmacotherapy of ADHD is the first but not last step toward the acquisition of the skills needed for complete and autonomous adult functioning. Currently, there is a growing recognition that treatment options for adult ADHD should include additional cognitive and behavioral interventions that take into consideration the comprehensive implications of the disorder, its functional outcomes and overall quality of life (Adler et al., 2008; Brod et al., 2006; Dodson, 2005; National Institute for Health and Clinical Excellence, 2013; Solanto et al., 2008).

The focus of this study is on a computerized cognitive training (CCT) program for adults with ADHD. The goal of cognitive intervention in individuals with ADHD is to remediate deficiencies in cognitive processes. Broadly defined, brain training refers to the engagement in a specific program or activity that aims to enhance a cognitive skill or general cognitive ability as a result of repetition over a circumscribed time frame (Rabipour & Raz, 2012). Cognitive programs include direct training with tasks that challenge cognitive skills such as working memory, inhibition or attention, by repeated and graded exposure to cognitive stimuli (Rabipour & Raz, 2012; Toplak, Connors, Shuster, Knezevic, & Parks, 2008). Brain training is especially relevant for developmental psychopathology. This approach has potential to ameliorate undesired symptoms of disorders such as ADHD (Rabipour & Raz, 2012). Advantages to the use of computerized programs are that there is explicit control of the intervention (i.e., treatment integrity), there can be longer training times and control of task demands (Riccio & Gomes, 2013). However, limitations may include questionable ecological validity, as well as high demand for recruiting effort and persistence in training program. Few of the cognitive intervention studies have targeted EF deficits in children, adolescents, and adults with ADHD. Most of the participants in these studies included children who were diagnosed with ADHD (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Chacko et al., 2014; Green et al., 2012; Johnstone, Roodenrys, Phillips, Watt, & Mantz, 2010; Johnstone et al., 2012; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002; O'Connell et al., 2006; Rabiner, Murray, Skinner, & Malone, 2010; Shalev, Tsal, & Mevorach, 2007; Steiner, Sheldrick, Gotthelf, & Perrin, 2011). The participants in the study of Karatekin

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(2006) and Beck and colleagues (2010) were adolescents with ADHD, whereas in the study of White and Shah (2006) and Virta and colleagues (2010), the participants were adults with ADHD. The attention-EFs that were targeted in the studies were inhibitory control (Johnstone et al., 2010; Johnstone et al., 2012; Karatekin, 2006; Virta et al., 2010), sustained attention (O'Connell et al., 2006; Rabiner et al., 2010; Shalev et al., 2007; Steiner et al., 2011; Virta et al., 2010), selective attention (Shalev et al., 2007; Virta et al., 2010), orienting of attention, executive attention (Shalev et al., 2007), attention-switching ability (Virta et al., 2010; White & Shah, 2006), and working memory (Beck et al., 2010; Chacko et al., 2014; Green et al., 2012; Johnstone et al., 2010; Johnstone et al., 2012; Klingberg et al., 2005; Klingberg et al., 2002; Virta et al., 2010). CCT is widely used in the last few years, and it was used in several of the studies mentioned above (Beck et al., 2010; Chacko et al., 2014; Green et al., 2012; Johnstone et al., 2012; Klingberg et al., 2005; Klingberg et al., 2002; Rabiner et al., 2010; Shalev et al., 2007; Steiner et al., 2011; Virta et al., 2010).

Positive effects of the cognitive training have been demonstrated on training tasks, similar tasks (near transfer), and neuropsychological measures in these studies. In addition, positive, yet inconclusive evidence of cognitive training for treating core symptoms in children and adolescents with ADHD was found in some of these studies (Beck et al., 2010; Sonuga-Barke et al., 2013). However, additional evidence is needed to confirm these initial findings, especially concerning adults with ADHD. Still, the knowledge about the applicability and generalization effects of cognitive training intervention to improve functional deficits and performance in daily activities and settings, beyond the training context, is not well-established (Green et al., 2012; Rabipour & Raz, 2012; Rapport, Orban, Kofler, & Friedman, 2013; Riccio & Gomes, 2013; Rutledge, van den Bos, McClure, & Schweitzer, 2012). Moreover, current models in cognitive rehabilitation of adults with neurological involvement stress the notion that cognitive skills may not be transferable from training tasks to everyday life (Toglia, 2005). Only few of the studies presented examined the outcome of cognitive training on everyday life in ADHD (Chacko et al., 2014; Green et al., 2012; Johnstone et al., 2012; Rabiner et al., 2010; Shalev et al., 2007; Steiner et al., 2011; Virta et al., 2010), and most of them included children as participants. Thus, to examine the "real world" ecological impact of such intervention in adults with ADHD, it is necessary to include outcome measures of everyday functioning, real-life settings, and quality of life.

Therefore, the objective of this study was to further examine the effect of CCT for adults with ADHD in a randomized controlled design. Specifically, we wanted to examine the effect of the training on EFs in daily life, on occupational performance and on quality of life. The primary outcome measures of the study were the measures of EF and the secondary outcome measures were the measures of ADHD symptomatology, occupational performance, and quality of life. The study hypotheses were as follows:

Hypothesis 1: A significant main effect of time (pre–post-training) will be found, within the study group, on measures of ADHD symptomatology (Adult ADHD Self-Report Scale [ASRS-v1.1] Symptom Checklist), neuropsychological measures of EFs (IntegNeuro™ test battery) and on measures of everyday EFs (Behavior Rating Inventory of Executive Function–Adult Version [BRIEF-A]), occupational performance (Canadian Occupational Performance Measure [COPM]), and ADHD-related quality of life (Adult ADHD Quality-of-Life Scale [AAQoL]).

Hypothesis 2: A significant interaction (Group × Time) effect will be found on all outcome measures.

Method

Participants

Participants for the study were recruited through an advertisement offering CCT for adults with ADHD at a university research center (Title: The efficacy of computerized cognitive training in adults with ADHD: Change in ADHD symptoms, executive functions and quality of life following three months of training; http://clinicaltrials.gov/show/NCT00843141). The conditions of the study were presented and participants were asked to contact the researcher for more information. Inclusion criteria included (a) adults (age 18-60); (b) sufficient reading skills to complete questionnaires; (c) a previous medical diagnosis of ADHD (any subtype) by a qualified medical professional (psychiatrist or neurologist); (d) scores above the cutoff on ADHD screening questionnaires (Wender Utah Rating Scale [WURS] score above 36, at least four out of six items in Part A of the ASRS-v1.1 Symptom Checklist); (e) verification of the diagnosis by a structured clinical interview implementing *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; APA, 2000) criteria (utilizing the gold criteria for ADHD diagnosis); (f) score of 65 or more on one or more of the scales of the BRIEF-A; (g) no change in pharmacological treatment in the last 3 months; and (h) without other new treatment for ADHD in the last 3 months. Exclusion criteria were (a) acute neurological or psychiatric disorders as defined by the Structured Clinical Interview for *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; APA, 1994) Axis I Disorders (SCID-I; First, Spitzer, Gibbon, & Williams, 1997), (b) current substance abuse, and (c) color blindness (due to program's demands). Clinical interviews were administrated by an experienced psychiatrist.

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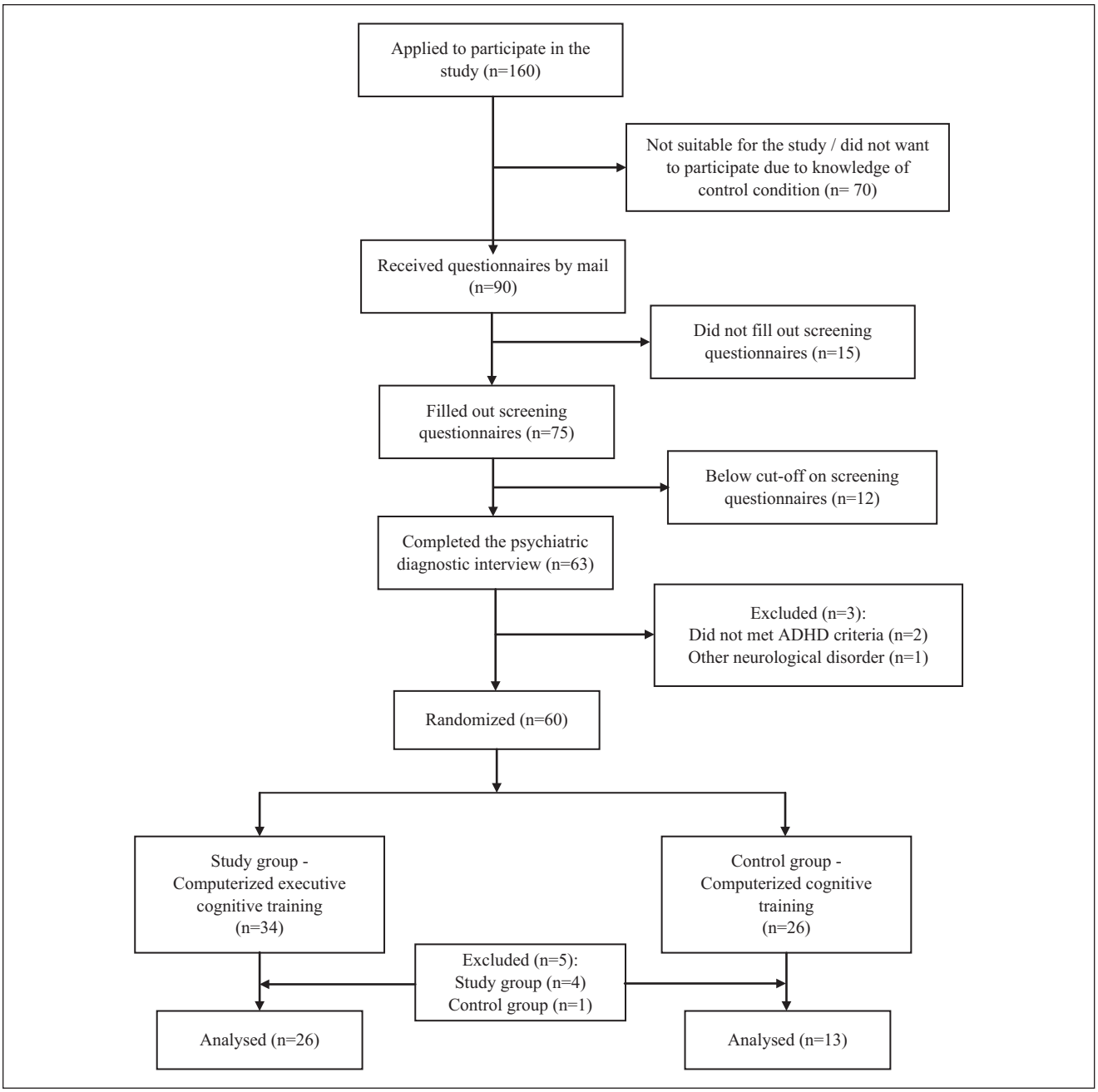

Figure 1. CONSORT flow diagram.

Final Sample

A total of 160 individuals applied to the study and contacted the researcher. Seventy of them were not suitable for the study (without a medical diagnosis of ADHD, did not meet age criteria, previous use of the study program) or did not want to participate in the study after receiving initial explanation about study design (possibility to be included in the control group). Ninety individuals received the WURS, ASRS, and BRIEF-A questioners, and 75 completed them and returned them to the researcher. Twelve of the 75 did not score above the cutoff on ADHD screening questionnaires. Sixty-three participants went through a psychiatric diagnostic interview and 60 adults met inclusion criteria and were qualified for the study. Participants were randomly allocated to one of the two groups using a computerized randomization program that was conducted by a senior researcher who did not participate in data collection processes (see Figure 1 for CONSORT flow diagram). Participants and investigator remained blind to the allocation till the completion of the post-training assessment.

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Measures

Measures for ADHD diagnosis

WURS. The WURS (Ward, Wender, & Reimherr, 1993) is a 25-item self-report questionnaire for the retrospective assessment of childhood ADHD symptoms; high scores indicate greater symptoms. The original scale consists of 61 items assessing symptoms of childhood ADHD, with 25 of these items used to differentiate ADHD adults from a non-patient comparison group. The WURS has been shown to have good internal consistency and temporal reliability (Stein et al., 1995) and was validated in a study by Ward and colleagues (1993).

ASRS-v1.1 Symptom Checklist. The ASRS-v1.1 Symptom Checklist (Kessler et al., 2005) is an instrument designed to measure current ADHD symptoms. It consists of 18 items based on the *DSM-IV* (APA, 1994) criteria for ADHD that are measured on a 5-point scale (0 = *never* and 4 = *very often*), yielding scores that may range from 0 to 72. A screener score comprised of the first six items of the ASRS (Part A) can also be computed, yielding scores that may range from 0 to 24 (Kessler et al., 2007). These six items were found to be the most predictive of symptoms consistent with ADHD. If four or more items are impaired within Part A, then the patient has symptoms highly consistent with ADHD in adults and further investigation is warranted (as done in the current study by a psychiatrist). The frequency scores on Part B (the remaining 12 questions) serve to further describe the patient's symptoms.

Neurocognitive measure

"IntegNeuro™" assessment (Brain Resource Company, Ltd., Sydney, Australia). A neuropsychological test battery consisting of 12 tasks that assess five cognitive domains: sensory-motor, learning and memory, language, attention and working memory, and EF/planning. It is administered on a computer using a touch-screen interface and voice recording, and takes approximately 50 min to complete (Clark et al., 2006). The measure has established norms based on normative cohorts from the Brain Resource International Database, comprising healthy individuals from several different countries, including the United States, United Kingdom, and Australia (n = 2,623) aged 6 to more than 89 years (Clark et al., 2006; Paul et al., 2007; Paul, Haque, et al., 2005). The battery has adequate test–retest reliability (r = .35-.81) and cross-site reliability, indicating high degree of similarity in cognitive function among individuals in developed countries (Europe, Australia, and the United States; Paul et al., 2007). The convergent validity of the tests was established in relation to commonly used paper-and-pencil cognitive assessments (r = .53-.77; Paul, Lawrence, et al., 2005). In this study, we analyzed the "IntegNeuro™" measures of working memory, sustained attention, intrusions, inhibition, response variability, and fluency that are used in ADHD research (Williams et al., 2005; Williams et al., 2010).

Ecological measures of everyday functioning and quality of life

BRIEF-A. A standardized self-report measure that captures adults' views of their EFs in their everyday environment (Roth et al., 2005). It is designed for adults with a wide variety of developmental disorders and systemic, neurological, and psychiatric illnesses. The BRIEF-A is composed of 75 items rated on a 3-point scale that encompass nine theoretically and empirically derived clinical scales measuring various aspects of EF (Inhibit, Shift, Emotional Control, Self-Monitor, Initiate, Working Memory, Plan/Organize, Task Monitor, Organization of Materials) that form two indices—the Behavioral Regulation Index (BRI) and the Metacognition Index (MI). The BRIEF-A was standardized in the United States on 1,136 healthy adults ages 18 to 90 and normative data are provided according to age groups (Roth et al., 2005). T-scores are calculated for each scale with higher scores indicating greater impairment. A score above 65 signifies clinical impairment. The BRIEF-A has moderate to high internal consistency (α = .73-.98), high test–retest stability (r = .82-.94), and moderate inter-rater agreement between self and informant report (r = .44-.68). Furthermore, non-English versions of the BRIEF-A, including a Hebrew version, were found to significantly differentiate adults with ADHD from adults without ADHD (Shan et al., 2011; Rotenberg-Shpigelman, Rapaport, Stern, & Hartman-Maeir, 2008).

COPM. The COPM (Law et al., 2005) is a standardized client-centered measure designed to identify individual occupational issues. The COPM is used to provide a measure of change in participant's individual occupational concerns on a 10-point scale. A change of 2 points in clients ratings are considered clinically significant for occupational performance (Law et al., 2005).

AAQoL Scale. The AAQoL (Brod, Perwien, Adler, Spencer, & Johnston, 2005) is one of the most commonly used disease-specific instruments to measure health-related quality of life in adults with ADHD both in research and clinical practice (Marfatia, Shroff, Munshi, & Tiwari, 2011). The AAQoL consists of 29 items rated on a 5-point scale relating to frequency of occurrence that yields a total score (based on all 29 items) and four subscale scores: Life productivity, Life Outlook, Relationships, and Psychological Health. Total and subscale raw scores are transformed to a 0- to 100-point scale with higher scores indicating better assessment of quality of life. The AAQoL has good internal consistency (α = .93), test–retest reliability (intraclass correlation coefficient [ICC] = .86), and discriminates between groups with and without ADHD (Brod et al., 2006; Matza, Johnston, Faries, Malley, & Brod, 2007; Matza et al., 2011).

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Procedure

This was a randomized, double-blind interventional study. The randomized controlled trial was registered at ClinicalTrials.gov (NCT00843141). The study was approved by the institutional review board ethics committee and the Helsinki Declaration. Participants, who responded to an advertisement of the study and had a diagnosis of ADHD that was made by a qualified medical professional, received a brief telephone explanation regarding the conditions of the study (assessment time, training time). If an oral consent was given, they were asked to fill out ADHD screening questionnaires (WURS, ASRS) and the BRIEF-A questionnaire. If the scores on the questionnaires were above cutoff, they were invited to an assessment meeting. In this meeting, participants received a complete description of the study, provided written consent and then proceeded with the evaluation. A face-to-face structured *DSM-IV-TR* (APA, 2000) criteria–based clinical interview was administrated by a psychiatrist for the confirmation of ADHD symptoms and evaluation of exclusion criteria (acute Axis I disorders and substance abuse). The participants were then completed additional questionnaires (demographic questionnaire, AAQoL, COPM), and the "IntegNeuro™" test battery was administered. At the end of the meeting, the participants received instructions in the use of the computerized program "AttenGo" and their personal username and password. In addition, an explanation about the training conditions was provided: (a) the training will be about 12 weeks long, (b) 4 to 5 times a week for at least 20 min, (c) at least 6 hr of sleep the night before. The participants were informed that a personal follow-up phone call will be made every 2 weeks, and training parameters (time, length, and performance) retrieved from the computer program. The participants were randomly assigned (using a computer generated randomized list) to the study or control group, with investigator and participants being blind to group assignment. Following the training period, a second assessment was conducted. Participants who attended the second assessment were considered "completers" and their data was analyzed. These participants received a license to continue using the program for a period of another 9 months (for the study group) or a year (for the control group).

The Training

The training was conducted with the computerized "AttenFocus" program of the "AttenGo" online cognitive training system (www.attengo.com). The program utilizes neutral universal stimuli (e.g., circles and squares). The training is organized in a hierarchical structure, is continuously adjusted to individual performance, and delivers immediate feedback on performance. The program focuses on cognitive skills including working memory, inhibition, shifting, selective and divided attention, and persistence. The training tasks require timely and accurate responses to changes in the stimuli with increasing working memory demands provided by conditional instructions (e.g., "Press once as quickly as you can when the ball changes color, but do not press any key when the color is white" or "Focus on the ball and listen to the tone. When the ball changes color, press the space bar, but when you hear the tone wait for the next color change"). The control group received a control program comprised of a simple non-hierarchical version of the "AttenFocus" with less executive demands. The control program training tasks required the same timely response to stimulus changes as in the original program but without the additional conditional instructions. All training was conducted online and performance parameters were automatically recorded and stored. Training effects in each training program were measured by scores on the training sessions. Every two weeks, a follow-up phone call was made by the researcher to all participants.

Statistical Analysis

Statistical analysis was performed with the SPSS Version 20.0. Mean, standard deviation, and percentages were used for baseline characteristics and *t* test or chi-square were performed where appropriate. Because the primary research goal was the study of a new treatment, we chose to use a non-intent-to-treat (non-ITT) approach to measure the effect of the experimental treatment (Ten Have et al., 2008). The treatment effects were investigated using repeated measures by group analyses on outcome measures (ASRS, BRIEF-A, AAQoL, COPM, "IntegNeuro" battery). Survival analysis using Kaplan–Meir method and Log rank test were used to determine whether there was a difference between study and control groups in training time.

Results

Sixty adults with ADHD (26 men, 34 women) with a mean age of 37.31 years (SD = 10.11, range = 19-57) were enrolled in the study. All participants met the *DSM-IV-TR* (APA, 2000) criteria for the diagnosis of ADHD, the majority were diagnosed with predominately inattentive type (n = 29). The mean total score of the ASRS was M = 45.75 (SD = 7.95) and of the ASRS Screener was M = 15.87 (SD = 2.91). Participants were randomly assigned to either the computerized "AttenFocus" training group (n = 34) or the control program group (n = 26; Figure 1) (The unequal number of participants at baseline in the two groups was found after completion of the study, when blindness was broken, and is a random occurrence). No significant differences were found between study and control groups on demographic variables as well as on all study variables before the cognitive training. There were no significant

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Table 1. Description of Study and Control Groups on Demographic and Study Measures.

	Study group (n = 34)	Control group (n = 26)	
	n (%)	n (%)	p value
Number male	15 (44)	11 (42)	.89
Number married	14 (41)	12 (46)	.10
Pharmacological treatment for ADHD	13 (38.2)	10 (38.5)	.89
	$M \pm SD$	$M \pm SD$	p value
Age in years	37.99 ± 10.36	36.41 ± 9.90	.55
Years of education	16.12 ± 2.58	15.00 ± 2.74	.11
WURS total score	57.21 ± 16.61	55.73 ± 15.93	.73
ASRS total score	45.79 ± 8.46	45.69 ± 7.40	.96
BRIEF-A BRI	66.65 ± 12.11	70.58 ± 11.16	.20
BRIEF-A MI	79.18 ± 7.77	79.12 ± 11.20	.98
COPM performance score	3.95 ± 1.35	3.50 ± 1.43	.22
AAQoL total score	51.98 ± 14.05	46.06 ± 15.43	.13

Note. WURS = Wender Utah Rating Scale; ASRS = Adult ADHD Self-Report Scale Symptom Checklist; BRIEF-A = Behavior Rating Inventory of Executive Function–Adult Version; BRI = Behavioral Regulation Index; MI = Metacognition Index; COPM = Canadian Occupational Performance Measure; AAQoL = Adult ADHD Quality-of-Life Scale.

differences on core symptoms measures (WURS, ASRS) and on ecological measures of everyday functioning and quality of life (BRIEF-A scales, indices and global score, AAQoL, COPM performance score) as reported in Table 1. Furthermore, no significant differences were found between the groups on all neuropsychological tests in the "IntegNeuro™" assessment ($p > .05$) before the training.

Thirty-nine participants (65.0%) completed the cognitive training period and attended the second assessment. Five participants (8.33%), 4 from the study group and 1 from the control group, were excluded from the study due to change in treatment or difficulty meeting training conditions. A significant difference was found in the survival rates between the groups ($p < .005$), where in the study group 26 (76.5%) completed the training period, compared with 13 (50.0%) in the control group. Kaplan–Meir curves showed greater devotion to training for the study group ($p = .001$). No significant differences were found between "completers" and "drop outs" on demographic and all study variables (WURS, ASRS, BRIEF-A, AAQoL, COPM, and "IntegNeuro™" battery). A further analysis of baseline (before training) scores of "completers" only, in both study groups, revealed no significant differences in all study variables. The mean time of the cognitive training was 11:00 hr (SD = 04:19) for the study group and 10:23 hr (SD = 05:47) for the control group. No significant statistical difference ($p = .71$) was found between the groups on time of the computerized practice. Significant training effect was found on training tasks for the study group ($p = .00$), but not for the control group ($p = .98$).

The near transfer effects ("IntegNeuro") and the far transfer effects (BRIEF-A, ASRS, COPM, and AAQoL) of the training are presented (see Tables 2 and 3). The results for the neurocognitive "IntegNeuro" battery are presented in Table 2 according to cognitive domains. Overall, small and non-significant time effects were found, except for the "Sustained attention" domain with a medium effect size. No significant interaction effects were found on any of the test scores.

Regarding the BRIEF-A, significant time effects were found in the ratings of EF in daily life, on both indices (BRI and MI) with medium to large effect sizes (Cohen's d = .65-.97). No interaction effects were found. Reliability for the sample was Cronbach's $\alpha = .77$ for the BRI and .83 for the MI. A significant time effect showing a reduction in ASRS scores was found with moderate to large effect sizes. No interaction effect was found. The internal reliability of the ASRS for the sample was Cronbach's $\alpha = .74$.

Similarly, a significant time effect was found in the COPM performance ratings with medium effect sizes in both groups, and with no interaction effect. Upon using the clinically significant change criteria (≥2 points), it was found that six participants (23.08%) in the study group and one participant (7.69%) in the control group demonstrated clinical improvement. The rates of change were not significantly different between groups ($p = .24$). Regarding the AAQoL, small effect sizes were found with no significant time effect and no interaction effect. The reliability of the AAQoL in this sample was Cronbach's $\alpha = .92$ and for the scales .75 to .89.

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Table 2. *T*-Scores at Baseline and at Post-Training Assessment on "IntegNeuro™" Assessment Cognitive Domains.

	Baseline, *M* ± *SD*	Post-training, *M* ± *SD*	*M* (95% CI)	Cohen's *d*	*p* time	*p* interaction
Working memory						
Study group	46.05 ± 6.64	47.92 ± 7.63	−1.87 [−4.22, 0.48]	0.26	.31	.37
Control group	47.86 ± 8.39	47.96 ± 7.91	−0.10 [−3.38, 3.17]	0.01		
Sustained attention						
Study group	45.87 ± 13.04	50.80 ± 13.08	−4.93 [−10.73, 0.86]	0.38	.04*	.86
Control group	46.55 ± 9.13	50.72 ± 9.87	−4.17 [−9.15, 0.80]	0.44		
Inhibition						
Study group	45.78 ± 7.55	47.46 ± 5.82	−1.68 [−4.75, 1.39]	0.25	.14	.96
Control group	46.49 ± 5.37	48.28 ± 3.62	−1.79 [−4.36, 0.78]	0.39		
Intrusions						
Study group	47.99 ± 7.64	50.53 ± 7.56	−2.54 [−5.12, 0.03]	0.33	.17	.65
Control group	48.35 ± 7.24	49.62 ± 7.20	−1.27 [−7.80, 5.26]	0.18		
Response variability						
Study group	45.01 ± 9.86	44.89 ± 11.12	0.12 [−4.43, 4.68]	0.01	.36	.33
Control group	43.97 ± 11.32	47.45 ± 8.83	−3.48 [−9.20, 2.24]	0.34		
Fluency						
Study group	48.50 ± 9.23	50.88 ± 7.85	−2.38 [−5.44, 0.68]	0.28	.18	.50
Control group	48.03 ± 9.00	48.84 ± 8.74	−0.80 [−3.74, 2.13]	0.09		

Note. CI = confidence intervals.
*$p \leq 05$.

Table 3. Scores at Baseline and at Post-Training Assessment on Self-Ratings Measures.

	Baseline, *M* ± *SD*	Post-Training, *M* ± *SD*	*M* (95% CI)	Cohen's *d*	*p* time	*p* interaction
Total ASRS						
Study group	46.19 ± 7.60	36.73 ± 10.00	9.46 [6.34, 12.59]	1.07	.00**	.24
Control group	43.23 ± 8.66	36.92 ± 8.92	6.31 [1.67, 10.95]	0.60		
BRIEF-A BRI						
Study group	66.46 ± 11.25	59.46 ± 10.33	7.00 [3.50, 10.50]	0.65	.00**	.74
Control group	68.54 ± 12.15	60.46 ± 8.97	8.08 [1.74, 14.41]	0.74		
BRIEF-A MI						
Study group	78.15 ± 7.22	68.50 ± 12.07	9.65 [6.48, 12.83]	0.97	.00**	.95
Control group	79.62 ± 11.84	70.15 ± 11.52	9.46 [4.03, 14.89]	0.81		
COPM performance						
Study group	3.88 ± 1.26	5.08 ± 1.82	−1.20 [−1.73, −0.66]	0.77	.00**	.23
Control group	3.60 ± 1.18	4.28 ± 1.10	−0.68 [−1.31, −0.04]	0.60		
Total AAQoL						
Study group	52.52 ± 15.14	56.37 ± 16.79	−3.85 [−9.96, 2.27]	0.24	.33	.58
Control group	50.27 ± 16.57	51.33 ± 14.64	−1.06 [−9.42, 7.29]	0.07		

Note. CI = confidence intervals; ASRS = Adult ADHD Self-Report Scale Symptom Checklist; BRIEF-A = Behavior Rating Inventory of Executive Function–Adult Version; BRI = Behavioral Regulation Index; MI = Metacognition Index; COPM = Canadian Occupational Performance Measure; AAQoL = Adult ADHD Quality-of-Life Scale.
**$p \leq .01$.

Discussion

The current study was a randomized control trial examining the efficiency of CCT for adults with ADHD, comparing two training conditions with graded levels of executive cognitive demands. The influence of the interventions on ADHD symptoms, EFs in daily living, occupational performance, quality of life, and neurocognitive performance were evaluated. Participants in both groups demonstrated positive changes in ADHD symptomatology, as well as in ecological measures of EFs and occupational performance. However, regarding the measures of neurocognitive performance and quality of life, no significant changes were found, except for the "Sustained attention" cognitive domain of the

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"IntegNeuro™" battery. In addition, no significant time by group interaction effects were found in all study variables, indicating that both groups benefited similarly from the CCT with no advantage of one training condition over the other.

The study group demonstrated a significant improvement on their training tasks, whereas the control group showed no training effect. Since the control group trained on simple non-hierarchical tasks, it is likely that their pretraining performances on these tasks were high to begin with and therefore the scores on the training tasks remain the same. The high attrition rate in this group may be attributed to the repetitive nature of the training. Therefore, it is assumed that the "completers" in this group represent participants who were challenged in recruiting effort and sustaining attention to the task.

The issue of transfer and generalization of the cognitive training beyond training tasks to daily functioning is very central in the study of cognitive rehabilitation interventions (Green et al., 2012; Katz, 2011; Rabipour & Raz, 2012; Rapport et al., 2013; Riccio & Gomes, 2013; Rutledge et al., 2012; Toglia, 2005). Following is a discussion of the transfer effects to measures of near ("IntegNeuro™") and far (BRIEF-A, ASRS, COPM, AAQoL) transfer. Regarding the near transfer to the neurocognitive test battery, only the "Sustained attention" domain significantly improved, whereas no transfer effect was found in the other EF domains. This finding is in line with a recent meta-analysis, which reported that sustained attention was found to be one of the most promising candidates for this training in children with ADHD (Rapport et al., 2013). Far transfer effects were demonstrated to the BRIEF-A rating scale in both groups, indicating self-perceived improvement in executive functioning in their daily life. The mixed findings pertaining to near and far transfer effects on EF measures are similar to other research findings regarding EF responsiveness to CCT. Virta and colleagues (2010) found a significant change on EF ratings and not on a neurocognitive test battery. Other studies of children and adolescents found positive gains in EF rating scales (Beck et al., 2010) and in selected EF performance tests (Green et al., 2012; Johnstone et al., 2010; Johnstone et al., 2012; Karatekin, 2006; Klingberg et al., 2005; Klingberg et al., 2002; Shalev et al., 2007) and one study of adults found positive results on EF tasks (White & Shah, 2006). The variability in the research findings may be attributed to the use of different measures, to the nature and intensity of training or to the change mechanism of the training that will be discussed furthered on. Importantly, EF ratings have been shown to be more strongly associated with impairment in major life activities than neuropsychological testing (Barkley & Murphy, 2010, 2011; Brown et al., 2009). Therefore, positive improvements on the BRIEF-A provide ecological support for the training.

The improvements found in self-reported ADHD symptoms after cognitive training are similar to previous improvements found in children and adolescents on their parents' and teachers' ratings (Beck et al., 2010; Johnstone et al., 2010; Johnstone et al., 2012; Klingberg et al. 2005; Rabiner et al., 2010; Shalev et al., 2007; Steiner et al., 2011). However, Virta and colleagues (2010) did not find significant change on adults' ASRS scores after cognitive training. Furthermore, in the current study, despite the significant improvement, the mean ASRS scores of the participants after training remained within the clinically impaired range of ADHD. Regarding occupational performance and quality of life, overall, the training effect was limited. The vast majority of the participants reported no clinically significant change on their occupational issues (despite the statistically significant improvement) and no significant improvement was found on the total AAQoL score. Similar to our findings, no significant changes were found in adults ratings of quality of life after cognitive training (Virta et al., 2010). A comparison can be drawn to studies in children which examined transfer to learning and behavioral outcomes with inconclusive findings (Green et al., 2012; Shalev et al., 2007). These findings regarding different changes in self-report measures of functioning demonstrate the ability of participants to differentiate among areas of improvement and counter the notion of a uniform "positive treatment effect," thus supporting the reliability of their reports.

The pattern of the transfer results can be explained in several ways. First, the cognitive training may have a specific remedial effect on sustained attention that may generalize to functional tasks. However, it is difficult to explain the generalization from this specific moderate effect to the broad and large effects in EF that were reported on the BRIEF-A. Second, it is possible that the treatment was effective due to metacognitive learning. The experience in cognitive training tasks may have enhanced awareness to cognitive difficulties, which enabled the development and use of compensatory strategies (e.g., anecdotal reports of participants revealed that they began to notice their distractibility in social situations and attempted to consciously control their behavior). A third probable explanation is that the cognitive training was not effective, except for motivational-placebo effect. The invested motivational resources (time, effort) invested by all participants in the cognitive training may have led to positive expectations in treatment outcomes (placebo effect). However, this explanation may be questioned due to the variation in participants' reports on different areas of EF functioning, quality of life, and their occupational performance. A placebo effect would be expected to be generalized to all functional outcomes. Finally, it is possible that a combination of some or all of the above impacted the outcome. The reported effects in this study, as a result of cognitive training, together with a

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growing body of evidence (Rabipour & Raz, 2012; Rutledge et al., 2012), attest to a possible potential of such interventions in ADHD treatment yet do not support the inclusion of specific higher level executive training. Cognitive training may offer a path for improving some of the cognitive difficulties of the disorder for individuals who are interested and capable of meeting the training requirements. Further research is needed to examine the specific characteristics of training that may impact ADHD outcomes.

This is one of few controlled studies examining cognitive training in adults with ADHD. This study employed rigorous criteria for ADHD and included various ecological measures representing broad areas of functioning. However, this study has some limitations. Due to a large percentage of dropout in the control group, the sample of this group was small (n = 13) at the end of the training. This limitation might explain the absence of time by group interactions, as a result of insufficient statistical power. An additional study, with a larger sample is required to clarify the interaction effect. The blinding of the participants in the control group could have been damaged due to the simplicity of their training program and may explain the difference in attrition rate between the groups. Further studies will benefit from a better designed control training. Finally, there was no follow-up of the participants after the end of the training. Additional assessments (in one or more time points after training) may help to further establish the effectiveness of this kind of treatment for adults with ADHD.

Declaration of Conflicting Interests

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Author Biographies

Adi Stern, MSc, OTR, a doctoral student in the School of Occupational Therapy, Hadassah and Hebrew University, Jerusalem, Israel. Head of occupational therapy service in the department of adult psychiatry at Hadassah Medical Center, Jerusalem, Israel.

Elad Malik, MD, Hadassah-Hebrew University Medical School, Jerusalem, Israel. Psychiatry resident, department of psychiatry, Hadassah Medical Center, Jerusalem, Israel.

Yehuda Pollak, PhD in neuropsychology. Lecturer at the department of psychology, The Hebrew University of Jerusalem, Israel. Clinical neuropsychologist at the neuropediatric unit, Shaare Zedek Medical Center, Jerusalem, Israel.

Omer Bonne, MD, Associate professor of psychiatry, chair, department of psychiatry, Hadassah-Hebrew University Medical School, Jerusalem, Israel.

Adina Maier, PhD, School chair and director of graduate studies, School of Occupational Therapy, Hadassah and Hebrew University of Jerusalem, Israel. Director of neurocognitive rehabilitation laboratory.

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