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Title

A Pilot Study of Computerized Cognitive Training in Adults with Attention-Deficit/Hyperactivity Disorder: Change in Executive Functions and Quality of Life Following 3 Months of Training Using the AttenFocus^{TM}[1] Program

Key words: Adult Attention-Deficit/Hyperactivity Disorder; Executive functions; Cognitive training; Quality of life

[1] Users will use the computerized internet system: AttenFocus^{TM} of AttenGo^{TM}

Abstract

Objective: Executive function (EF) deficits in adults with ADHD have been shown to have a negative impact on everyday functioning and quality of life (QOL). Very few cognitive training studies have targeted EF deficits in individuals with ADHD. Although positive effects have been demonstrated on training tasks, neuropsychological and ADHD symptomatology measures, additional evidence is needed to confirm these findings as well as to examine the effects on EFs and QOL. Thus, the goal of this pilot study was to further examine the effect of computerized cognitive training for adults with ADHD on measures of ADHD symptomatology, EFs and QOL. **Method**: Adults with ADHD (n=14) trained on the AttenFocus™, an on-line computerized cognitive program. **Results**: Before and after comparison demonstrated significant, moderate to large effects of the training on all outcome measures. **Conclusion**: The findings provide preliminary supporting evidence for computerized cognitive training in adults with ADHD and warrant further controlled studies to examine its potential impact on functional outcomes

1. Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a chronic mental health disorder of childhood characterized by inattention, impulsiveness and hyperactivity (Diagnostic and Diagnostic and statistical manual of mental disorders, 4th edition [DSM-IV]; APA, 1994). Long-term controlled follow-up studies have shown that the disorder persists in a sizeable number of adults who were diagnosed as having ADHD in childhood, and the estimated prevalence of adult ADHD is approximately 4% of adults worldwide (Wilens, Faraone, & Biederman, 2004). ADHD is now increasingly recognized as a developmental impairment of executive functions (Brown, 2008). The term executive functions (EFs) refers to a wide range of higher cognitive processes that enable goal-directed behavior and play a critical role for all individuals as they manage multiple tasks of daily life. The EFs include response inhibition, initiation, implementing strategies for performance, shifting, intrusion control, working memory and control of complex cognitive or motor responses (Brown, 2008; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Lezak, Howieson, Loring, Hannay, & Fischer, 2004; Nigg, et al., 2005; Roth, & Saykin, 2004). Converging evidence points to a prominent disturbance in a wide range of EFs in children and adults with ADHD that impedes the quality of their daily lives (Biederman, et al., 2006, 2007; Nigg, et al., 2005; Roth, & Saykin, 2004).

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 (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, 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; Solanto, et al., 2008; Wilens, et al., 2004). Therefore, it is not surprising that adults with ADHD demonstrate serious compromises in their quality of life (Barkley, 2002; Barkley, et al., 2008; 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 executive functioning 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; Solanto, et al., 2008; Wilens, et al., 2004). 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, considerable number of adults with ADHD do not utilize this treatment due to several causes: a. lack of interest to use pharmacological treatment due to a variety of reasons (e.g. fear of size effects, negative believes about medication use); b. drug side effects (Dodson, 2005; Wilens, et al., 2004); c. 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). 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 in ADHD (O'Connell, et al., 2006; 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 of 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; Solanto, et al., 2008).

The focus of this study is on a cognitive training program for adults with ADHD. The goal of cognitive interventions is to remediate deficiencies in cognitive processes in individuals with ADHD. Cognitive programs include direct training of cognitive skills, such as working memory, inhibition or switching of attention, by repeated and graded exposure to cognitive stimuli (Toplak, Connors, Shuster, Knezevic, & Parks, 2008). Very few of the cognitive intervention studies have targeted EF deficits in children and adults with ADHD (Karatekin, 2006; Klingberg, et al., 2005; Klingberg, Forssberg, & Westerberg, 2002; O'Connell et al., 2006; Rapport, et al., 1996; Shalev, Tsal, & Mevorach, 2007; White, & Shah, 2006). Most of these studies included children that were diagnosed with ADHD as participants (Klingberg, et al., 2002; 2005; O'Connell et al., 2006; Rapport, et al., 1996; Shalev, et al., 2007). The participants in the study of Karatekin (2006) were adolescents with ADHD, whereas in the study of White and Shah (2006) the participants were adults with ADHD. The attention-executive functions that were targeted in the studies were inhibitory control (Karatekin, 2006), sustained attention (O'Connell et al., 2006; Rapport, et al., 1996; Shalev, et al., 2007), selective attention, orienting of attention, executive attention (Shalev, et al., 2007), reflectivity (Rapport, et al., 1996), attention-switching ability (White & Shah, 2006) and working memory (Klingberg, et al., 2002; 2005). Computerized training was used only in the studies of Klingberg and colleagues (2002; 2005) and Shalev and colleagues (2007).

Positive effects of the cognitive training have been consistently demonstrated on training tasks, near novel tasks and neuropsychological measures in all studies. However, additional evidence is needed to confirm these initial findings, especially concerning adults with ADHD. Moreover, current models in cognitive rehabilitation of adults with neurological involvement stress that cognitive skills may not transfer from training tasks to everyday life (Toglia, 2005). Therefore, in order examine the "real world" ecological impact of intervention, it is necessary to include outcome measures of everyday functioning, real-life settings and quality of life. Except for the study of Shalev and colleagues (2007) that used pre- and posttraining measures of academic performance for children, no studies have been found that examined the outcome of cognitive training on everyday life in ADHD.

Therefore, the objective of this pilot study was to further examine the effect of computerized cognitive training for adults with ADHD. Specifically, we wanted to examine the effect of the training on executive functioning in daily life, and on quality of life. **The study hypotheses were that** a significant main effect of time (pre-post training) will be found on a. neuropsychological measures of executive functions

(IntegNeuro test battery); b. measures of ADHD symptomatology [Adult ADHD Self-Report Scale (ASRS-v1.1) Symptom Checklist; Wender Utah Rating Scale (WURS)]; c. executive functioning in daily life [Behavior Rating Inventory of Executive Function – Adult Version (BRIEF-A)]; and d. ADHD related quality of life [Adult ADHD Quality-of-Life Scale (AAQoL)].

2. Materials and Methods

2.1. Participants

Recruitment for this study was through an advertisement in a local newspaper and on the website: www.krz.co.il. The conditions of the study were presented and participants were asked to call the researcher for more information. **Inclusion criteria were**: Adults (age 18-60); sufficient reading skills to complete questionnaires; diagnosis of ADHD (any subtype): a. by a qualified medical professional (psychiatrist or neurologist), b. scores above the cutoff on ADHD screening questionnaires [Wender Utah Rating Scale (WURS) score above 36; at least four out of six symptoms in part A of the Adult ADHD Self-Report Scale (ASRS-v1.1) Symptom Checklist; Brown Attention-Deficit Disorder (ADD) Rating Scale for Adults (BADDS) score above 45], c. verification of the diagnosis by a structured DSM-IV criteria based interview; signed informed consent to participate in the research; without change in pharmacological treatment in the last 3 months; without other new treatment for ADHD in the last 3 months. **Exclusion criteria were**: Acute neurological or psychiatric (axis I) disorders; current substance abuse; color blindness (due to program's demands).

Twenty-four adults with ADHD (16 men, 8 women) were enrolled in the study, after receiving an explanation through the phone and after providing initial oral consent. One subject did not meet inclusion criteria for ADHD (scores below cutoffs on ADHD questionnaires), therefore the study sample included 23 participants that were evaluated at the onset of the training. From the study sample, 14 (61%; 10 men, 4 women) completed the computerized training period and provided pre- and posttest measures. Completers had a mean age of 33.50 years (SD = 9.272, range 22-58) and a mean years of education of 15.36 (SD = 3.296, range 11-22). Five (35.7%) were married and nine (64.3%) were single. Ten (71%) of them received medication for ADHD.

2.2. Measures

Neuropsychological measure:

IntegNeuro test battery (Brain Resource Company, Ltd)

A neuropsychological test battery consisted of 12 tasks that cover five cognitive domains: Sensori-motor-spatial, verbal and nonverbal memory, language, attention and vigilance and executive function/planning. It administered on a computer using a touch-screen interface and voice recording, and takes approximately 50 minutes to complete (Clark, et al., 2006). All instructions are provided via headphones, and each test is preceded by a thorough explanation, visual examples of performance, and a practice trial. The battery has demonstrated validity, reliability and established norms from 6 to over 80 years (Paul, Lawrence, Williams, Clark, Cooper, & Gordon, 2005; Paul, et al., 2005; 2006; Williams, Simms, Clark, Paul, Rowe, & Gordon, 2005).

Measures for ADHD diagnosis:

Wender Utah Rating Scale (WURS; Ward, Wender, & Reimherr, 1993). The WURS 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 nonpatient 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).

Adult ADHD Self-Report Scale (ASRS-v1.1) Symptom Checklist (World Health Organization, 2003) is an instrument consisting of the eighteen DSM-IV-TR criteria. Six of the eighteen questions were found to be the most predictive of symptoms consistent with ADHD. These six questions are the basis for the ASRS v1.1 Screener and are also Part A of the Symptom Checklist. Part B of the Symptom Checklist contains the remaining twelve questions. The checklist takes about five minutes to complete and can provide information that is critical to supplement the diagnostic process.

Brown Attention-Deficit Disorder (ADD) Rating Scale for Adults (BADDS; Brown, 1996). The BADDS is a 40-item self-report inventory. This scale is based on a series of symptom descriptors reported by high school and college students with nonhyperactive ADD and is often used with highly functioning adults. The BADDS assesses 5 dimensions of symptoms which include organizing work, sustaining attention and concentration, sustaining alertness and effort, managing frustration and other emotions, and using working memory. The internal consistency of the BADDS is high (Cronbach's coefficient 〈 = .96).

Ecological measures of everyday functioning and quality of life:

Behavior Rating Inventory of Executive Function – Adult Version (BRIEF-A; Roth, Isquith, & Gioia, 2005). A standardized self-report measure that captures adults' views of their own executive functions in their everyday environment. It is designed for adults between the ages of 18 and 90 years with a minimum fifth-grade reading level, including those with a wide variety of developmental disorder and systemic, neurological, and psychiatric illnesses. The BRIEF-A is composed of 75 items within nine clinical scales that measure different aspects of executive functioning. The clinical scales form two broader indexes: the Behavioral Regulation Index (BRI) and the Metacognition Index (MI), and an overall summary score, the Global Executive Composite (GEC). The raw scores are transformed into T-scores (age depended and relative to normative groups). T-score above 65 in one of the scales, indexes or GEC is identified as an impairment. The BRIEF-A has moderate to high internal consistency (α=.73-.98) and high test-retest stability (r=.82-.94) and moderate interrater agreement (r=.44-.68) and was found to significantly differentiate between adults with and without ADHD (Rotenberg-Shpigelman, Rapaport, Stern, & Hartman-Maeir, 2008).

Adult ADHD Quality-of-Life Scale (AAQoL; Brod, Perwien, Adler, Spencer, & Johnston, 2005). The AAQoL was designed to assess health related quality of life (HRQL) during the past 2 weeks. It consists of 29 questions using a 5-point Likert scale for frequency of occurrence. Four subscale scores are derived: Productivity, life outlook, relationships, and psychological health. Total and subscale scores are computed, higher scores indicate better assessment of quality of life. The AAQoL has good internal consistency reliability and good construct and discriminate validity (Brod, et al., 2006; Matza, Johnston, Faries, Malley, & Brod, 2007) and is highly responsive to change (Matza, et al., 2007).

2.3. Design

Pilot study designed as experimental pre-and post training of one group of adults with ADHD.

2.4. Procedure

The study was approved by the institutional review board ethics committee.

Subjects, who responded to an internet 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 invited to an assessment meeting. The pre-training assessment refers to the current functioning at entry time to the study, and not to past functioning or to the period preceding diagnosis of ADHD.

Assessment meeting (about 4 hours long): The subjects were asked to fill out ADHD screening questionnaires (WURS, ASRS, BADDS). If the scores on the questionnaires were above cutoff, a face-to-face structured DSM-IV criteria based clinical interview was administrated by a psychiatric for the confirmation of ADHD symptoms and evaluation of exclusion criteria (acute axis I disorders and substance abuse). Subjects that were found suitable for the study received a complete description of the study and were asked to provide a written informed consent. The subjects were then asked to complete additional questionnaires (demographic questionnaire, BRIEF-A, AAQoL), and the IntegNeuro test battery was administered. At the end of the meeting the subjects received instructions in the use of the computerized program AttenFocus™ and their personal username and password. In addition, an explanation about the training conditions was provided: 1. the training will be 12 weeks long; 2. 4-5 times a week for at least 20 minutes; 3. at least 6 hours of sleep the night before. The participants were informed that a personal follow-up weekly phone call would be made, and training parameters (time, length, and performance) retrieved from the computer program.

Training by the AttenFocus™ program

The training was conducted with the Hebrew version of the computerized AttenFocus™ program (www.attengo.co.il), developed at the ACE (Advanced Cognitive Enhancement) clinic in Toronto, Canada. AttenFocus™ is an adaptive cognitive online training system designed for ages 6 and up. The program utilizes neutral universal stimuli (e.g. circles and squares) and is tailored to the individual, based on age and baseline performance on the training tasks. The training is hierarchic, is continuously adjusted to individual performance and delivers feedback. It focuses on executive cognitive skills such as working memory, inhibition, shifting and dividing attention and persistence. All training is conducted online and performance parameters are automatically recorded and stored. Computerized assessments are executed before the training and every 21 days throughout the training. A weekly follow-up phone call was made by the researcher to all subjects.

Final Assessment – after 3 months (about 3 hours long): The subjects were asked to complete the ASRS, BADDS, BRIEF-A and AAQoL questionnaires and the IntegNeuro test battery was administered. The participants received a license to continue using the program for a period of another nine months**.**

2.5. Statistical analysis

Statistical analysis was computed with the statistical software package SPSS – 15.0 version. Descriptive statistics were performed in order to describe the sample characteristics and the cognitive and functioning variables. Non parametric, Wilcoxon

Signed Rank test was computed to analyze pre-post differences (α=.05). Hedges g was calculated to measure effect size.

3. Results

Fourteen adults with ADHD completed the training program, whereas nine subjects discontinued their training. The subjects reported the reasons that they dropped out as follows: technical computer difficulties (3 subjects), life events (birth of a child, change of job -2 subjects), and difficulty persisting with practice regimen (4 subjects). There were no significant differences (p>.10) between the 'completers' and the 'drop outs' on demographic variables (age, gender, years of education), nor on any of the study measures (IntegNeuro test battery, ASRS, BADDS, BRIEF-A, AAQoL). In addition there were no significant differences on any of the study measures, between the subjects who were taking/not taking (10/4) medication for ADHD(p>.10). The subjects that completed the training program trained on the AttenFocus™ software program 3-5 times a week for approximately 20 minutes each time. The mean total training time for the group was 11:40 hours (SD=6:15).

3.1. Change in neuropsychological assessment (IntegNeuro test battery)

Analysis of the change on the IntegNeuro test battery revealed significant improvements in several measures of executive function and attention ('switching of attention', 'maze' and 'sustained attention'), effect sizes were small to moderate, while the improvements that were found on the other measures of the IntegNeuro test battery did not reach statistical significance (see table 1).

Insert Table 1 about here

3.2. Change in ADHD symptomatology (ASRS; BADDS)

Significant improvements were found on measures of ADHD symptomatology (ASRS; BADDS). A reduction was found in the reported severity of symptoms after the training for all subjects, except for one subject that reported increased severity of symptoms (8% increase on the BADDS). The effect size on the ASRS was large and on the BADDS was moderate (see table 2).

Insert table 2 about here

3.3. Change in executive functioning scores in daily life (BRIEF-A)

Significant improvements were found on the BRIEF-A global score, indices, and 7/9 scales after training (see table 3). Effect sizes were moderate to large (Hedges g=.32-1.09) with the largest size effects on the 'inhibit' scale and 'BRI' index. The frequencies of the individual BRIEF GEC profiles (see figure 1) revealed that after training the scores improved (decreased) for 13 of the subjects while one score remained the same [range of the change 0-(-22), M=-9.00 (SD=6.67)]. In addition, prior to the training, the GEC scores of 12 subjects were in the impaired range (T-score≥ 65) whereas after the training the scores of five of these subjects were within the normal range (<65).

Inset table 3 and figure 1 about here

3.4. Change in Quality of life (AAQoL)

Significant improvements were also found on the measure of quality of life (AAQoL) on the total score and on all four subscales. The total score for 13 of the subjects improved (increased) after the training, while one score remained the same [range of the change .00-28.97, M=11.15, (SD=8.69)]. Pre-post comparisons were significant at $p \leq .01$, and effect sizes were all large (Hedges g = .66- 1.15) (see table 4).

Insert table 4 about here

4. Discussion

The findings of the current study provide preliminary supporting evidence for computerized cognitive training for adults with ADHD. Participants in the study demonstrated significant positive changes in ADHD symptomatology as well as in measures of executive functioning and quality of life. The current study adds to the body of evidence regarding the efficacy of cognitive treatment for individuals with ADHD. The positive effects that were found on computerized tasks and neuropsychological measures are in line with previous cognitive training studies in children and adults with ADHD (Dowsett, & Livesey, 2000; Karatekin, 2006; Klingberg, et al., 2002; 2005; O'Connell et al., 2006; Rapport, et al., 1996; Shalev, et al., 2007; White, & Shah, 2006). However, the unique contribution of the current study lies in the additional real-world outcomes with established clinical significance.

We found improvements in EFs in objective cognitive testing (IntegNeuro test battery) as well as in subjective report of executive functioning in daily life (BRIEF-A). It is noteworthy that the largest effects were found on the 'Inhibit' scale and the 'BRI' index (Hedges g = 1.09). This finding may have particular clinical value and future potential for individuals with ADHD, since hierarchical models of EF and ADHD conceptualize inhibition at the base of the hierarchy, which further influences the other EFs (e.g. working memory and behavioral regulation) (Barkley, 1997; Barkley et al., 2008). In addition to the change in cognitive measures, we also found very large pre-post effects in the quality of life and ADHD symptomatology outcomes measure. In adults, ADHD symptoms are associated with impairment in multiple domains that are considered to be key aspects of health related quality of life, a subjective perception of the impact of health status (Matza, et al., 2007), which is an important aspect to be measured in adult ADHD.

There is need to question the mechanism of change underlying these positive findings which may be attributed to several possible processes: (1) remediation of executive functions core abilities (e.g. inhibition, shifting, planning) that transferred to daily life; (2) metacognitive effect, whereby the experience in cognitive training tasks 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 impulsivity in social situations and attempted to consciously control their behavior); (3) the invested motivational resources (time, effort) in the cognitive training led to positive expectations that were perceived in the participant's subjective outcome reports; and finally, (4) a combined effect of improved cognitive ability, awareness and strategy utilization, motivation and positive expectations. The current study methodology cannot test the contribution of the above processes or the interactions among them. Further research, controlling for motivational processes (placebo training), exploring awareness and strategy use, and examining the relationship between the degree of improvement in cognitive and functional measures, is required to shed light on the underlying mechanisms of cognitive training benefits.

It is noteworthy that the effects of cognitive training found in this study are comparable to the effects that were found in pharmacological treatment studies of ADHD. The effect sizes of the training in this study for ADHD symptoms, executive functioning and quality of life were all moderate to large (between 0.32-1.15). In comparison, stimulants medications have been shown to have a large effect size, and the second-line medications (nonstimulant) as a group have been shown to have a moderate one, for reducing ADHD symptoms (Dodson, 2005; Michelson, Adler, & Spencer, 2003). This comparison is encouraging, suggesting a possible second -order treatment option for individuals who may not be able to benefit from pharmacological treatment (Dodson, 2005; Wilens, et al., 2004). On the other hand, considering that a large percent of the sample (71%) were also treated with medication, the findings may also suggest a combined benefit of cognitive training and medication, as has been shown by Rostain and Ramsay (2006). The therapeutic effects of stimulant medication are known to enhance concentration and reduce hyperactivity (Stevenson, Whitmont, Bornholt, Livesey, & Stevenson, 2002). Therefore, one could hypothesize that pharmacological treatment may improve the attention of individuals, thereby furthering their ability to benefit from a higher level executive cognitive training program. However, Stevenson and colleague (2002) found that non-medicated adult participants with ADHD responded to a cognitive remediation program as well as medicated participants. Therefore, further studies on cognitive training in larger samples which control for medication use, will determine the unique or cumulative contribution of cognitive and pharmacological treatments.

Besides the inherent weaknesses in an open-label design, our study has some additional limitations. Concerning the current study sample, the rigorous criteria utilized for ADHD, verified that the sample represents individuals with a valid diagnoses of ADHD. However, the subtype of the disorder was not taking into consideration in the process of analyzing the findings. It is important to examine whether there is a difference in the results of the training among the subtypes of the diagnosis. In addition, the sampling was based on response to an internet advertisement which may bias the sample in terms of representing educated adults that are aware of their diagnoses and are actively seeking information and treatment options for their ADHD. Furthermore, the training required the recruitment of motivational resources in order to persist and complete the 12 week computerized training period. Therefore, the final sample (61% of the initial sample) was probably characterized by high motivation. Thus the findings of the current study may not be generalized to the ADHD adult population at large, and may be limited to a sub group of adults with high motivation for improvement.

In summary, as ADHD in adults becomes increasingly recognized, it is important to find more effective treatments in addition to the use of pharmacological treatment. While this study is only preliminary, the findings suggest that computerized cognitive training may assist adults with ADHD in improving their executive functions and their quality of life. Further studies are needed, with a representative sampling and placebo control group, including metacognitive measures and follow up assessments, in order to verify these initial findings, their stability over time, as well as examine their underlying mechanisms.

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Table 1. Comparison of the IntegNeuro test battery scores before and after training

	Time 1 Before practice	**Time 2 After practice**		
IntegNeuro test battery	Mean (SD)	Mean (SD)	Z (p)	Hedges g
Digit Span				
Recall span (forwards)	6.46 (1.71)	6.46 (1.56)	-.159 (.437)	0
Recall span (backwards)	4.85 (2.04)	5.54 (1.81)	-1.195 (.116)	.34
Sustained Attention (CPT)				
Reaction time (ms)	457.92 (111.323)	409.42 (124.56)	-1.490 (.068)	.39
False alarms*	1.42 (2.07)	.33 (.49)	-1.725 (.042)	.69
False misses	1.08 (1.56)	.58 (.90)	-.938 (.174)	.37
Switching of Attention				
Completion time (digits) (s)*	21.54 (7.73)	18.17 (3.91)	-1.958 (.025)	.52
Completion time (digits+letters) (s)	45.76 (13.99)	40.29 (12.47)	-1.503 (.067)	.39
Choice Reaction Time				
Reaction time (ms)	828.10 (352.38)	704.40 (188.07)	-1.478 (.070)	.41
Time Estimation				
Accuracy (s)	-.03 (.27)	-.02 (.26)	-.105 (.458)	.04
Maze				
Completion time (s)	223.31 (82.10)	191.62 (77.28)	-1.54 (.062)	.38
Total errors*	43.77 (22.79)	30.77 (19.36)	-2.029 (.022)	.68
Number of overruns*	19.00 (15.06)	13.92 (12.87)	-1.771 (.039)	.34

*Significant group difference.

Table 2. Comparison of the ASRS and BADDS scores before and after training

	Time 1 – Before practice			**Time 2 – After practice**				
	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Z (p)	Hedges g
ASRS*	45	79	62.42 (9.69)	46	70	53.58 (6.72)	-2.831 (.003)	1.03
BADDS*	51	111	82.83 (20.09)	42	113	71.25 (23.04)	-2.279 (.012)	.52

Note: ASRS = Adult ADHD Self-Report Symptom Checklist; BADDS = Brown Attention-Deficit Disorder (ADD) Rating Scale for Adults.
*Significant group difference.

Table 3. Comparison of the BRIEF-A T-scores before and after training

	Time 1 – Before practice			**Time 2 – After practice**				
BRIEF-A (T-scores)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Z (p)	Hedges g
Inhibit*	48	74	61.50 (8.46)	41	65	53.29 (5.90)	-3.06 (.001)	1.09
Shift	51	91	61.71 (10.09)	47	74	58.71 (8.30)	-1.33 (.092)	.32
Emotional Control*	53	84	64.71 (10.42)	43	77	58.14 (10.88)	-3.08 (.001)	.60
Self-Monitor*	42	72	54.21 (9.35)	37	63	46.50 (8.29)	-3.19 (.001)	.85
BRI*	51	72	63.64 (7.40)	47	68	55.71 (6.72)	-3.30 (.001)	1.09
Initiate*	53	87	68.71 (13.54)	43	81	61.21 (13.84)	-2.95 (.002)	.53
Working Memory	63	95	77.79 (9.47)	56	92	72.79 (11.45)	-1.65 (.050)	.46
Plan/Organize*	57	94	72.57 (11.39)	41	80	63.00 (12.79)	-3.05 (.001)	.77
Task Monitor*	60	88	74.14 (9.15)	52	83	66.29 (9.14)	-2.55 (.006)	.83
Organization of Materials*	41	83	64.86 (12.93)	37	83	58.21 (14.58)	-2.37 (.009)	.47
MI*	58	92	74.79 (10.84)	47	82	66.21 (12.05)	-2.95 (.002)	.73
GEC*	57	86	71.71 (8.35)	47	74	62.71 (8.97)	-3.19 (.001)	1.01

Note: BRIEF-A = Behavior Rating Inventory of Executive Function – Adult Version; BRI = Behavioral Regulation Index; MI = Metacognition Index, GEC = Global Executive Composite.
*Significant group difference.

Table 4. Comparison of the AAQoL scores before and after training

	Time 1 – Before practice			Time 2 – After practice				
AAQoL	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Z (p)	Hedges g
Total Score*	40.69	73.79	54.43 (9.79)	45.52	78.62	65.58 (9.37)	-3.233 (.001)	1.13
Life productivity*	30.91	83.64	50.52 (14.41)	38.18	85.45	63.12 (13.50)	-2.858 (.002)	.88
Psychological health*	30.00	70.00	55.00 (10.76)	40.00	86.67	69.05 (12.97)	-3.207 (.001)	1.15
Life outlook*	28.57	74.29	54.29 (11.81)	48.57	74.29	62.10 (8.88)	-2.576 (.010)	.73
Relationships*	48.00	88.00	62.57 (12.31)	44.00	96.00	71.71 (14.67)	-2.408 (.008)	.66

Note: AAQoL = Adult ADHD Quality of Life Questionnaire.
*Significant group difference.

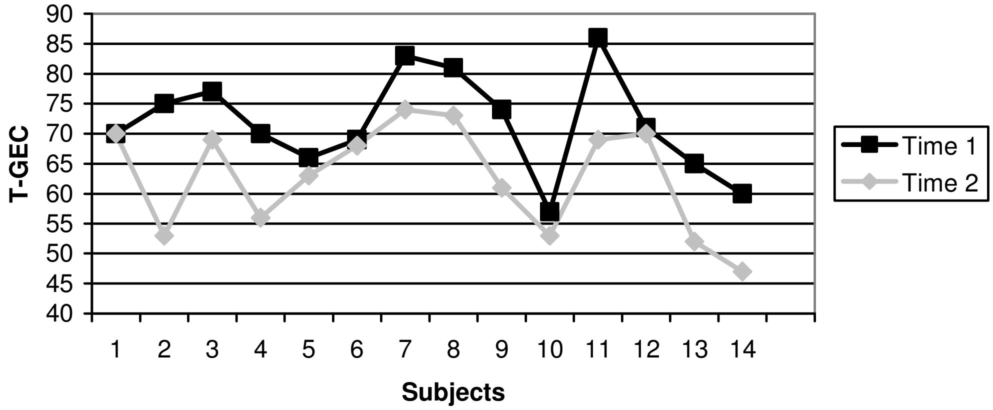

Fig. 1. Global Executive Composite (GEC) T-scores of the Behavioral Rating Inventory of Executive Function - Adult Version (BRIEF-A) before and after training for each subject.