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COMPUTER-ASSISTED INSTRUCTION OF MATHEMATICAL OPERATIONS IN ADHD AND TYPICAL STUDENTS – THE ONLINE LEARNING EXPERIENCE

George Botsas[1i],
George Grouios[2]
[1]Greek Ministry of Education & Frederick University,
Greece
[2]Aristotle's University of Thessaloniki,
Greece

Abstract:
This study examines the effectiveness of Computer – Assisted Instruction (CAI) on mathematical operations of addition and subtraction performance of students diagnosed with Attention Deficit / Hyperactivity Disorder and their typical peers, in the context of an online Learning Management System. The mathematical operation performance of students was assessed right before, just after and after three months' time in "paper and pencil" and CAI conditions in order to determine maintenance of intervention's effects. Six ADHD students diagnosed by public centers of diagnosis and attending 1st to 3rd grades of elementary school took part in the study. They were facing minor to major difficulties in mathematical operations of addition and subtraction. Twelve typical students of the same age and with no mathematical difficulties also took part. The research method was an experimental 2 (groups) X 4 (conditions) nonequivalent-control group design was created as students were different by ADHD existence. Typical students had significantly better performance in mathematical operations prior, after and in CAI implementation compared to the ADHD students with major problems. Their performance was actually in the same levels with students with ADHD with minor difficulties. Examination of within ADHD subjects revealed significant differences when CAI implemented. CAI found to be an effective instructional strategy on mathematical operations' performance either of students with ADHD or non-disabled in a "working at home" educational setting. Although all students had gains from CAI implementation, a "Mathew" effect was revealed, as typical and ADHD students with minor difficulties had better performance gains which were maintained more after treatment and a follow up examination after three months.

[i] Correspondence: email gbotsas@sch.gr

Keywords: computer-assisted instruction, attention deficit / hyperactivity disorder, mathematical operations, software, learning management system, home, educational environment, maintenance

1. Introduction

Over the past thirty years, Attention Deficit Hyperactivity Disorder (ADHD) has become a worldwide phenomenon (Sood & Sood, 2016) and the last ten years a real hot point of discussion in Greece (Vergou, 2018). ADHD is a neurodevelopmental disorder, applied to children who exhibit a rather inappropriate developmental profile in various settings, concerning attention, hyperactivity, and impulsivity (APA, 2013). Although it formulates a rather heterogeneous population (Polanczyk, De Lima, Horta, Biederman & Rohde, 2007; Wåhlstedt, Thorell & Bohlin, 2009), three subtypes recognized in ADHD profile, which is an inattentive (ADD), a hyperactive – impulsive one and a combined type.

According to the Greek government, laws 3699/2008 and 4186/2013, ADHD students attend mainstream school classrooms. They usually get compensatory help of a second teacher, teaching in a parallel way with the mainstream one. The estimation of ADHD students in school-aged population in Greece is between 5% to 12.4% (Skounti, Giannoukas, Dimitriou, Nikolopoulou, Linardakis & Philalithis, 2010; Zournatzis, Kakouros, Karamba, Papaeliou & Badikian, 2001). Although the number of those students rises up (Kalantzi-Azizi, Aggeli & Efstathiou, 2005), schools and teachers receive minimal training for treating them and focus of concern is only for their behavior and academic performance.

2. Literature Review

Their maladaptive and developmentally inappropriate profile affects their school and home efforts on their overall academic achievement (Brand, 2002; DuPaul & Volpe, 2009). Children with ADHD are often described as having performance and not skills deficits (Barkley, Fischer, Smallish & Fletcher, 2002; Daley & Birchwood, 2010) as their intelligence do not differs than normal students' distribution (Barron, Evans, Baranik, Seprell & Burnger, 2006; Kaplan, 2000).

An extensive body of research is established, implying that students with ADHD have problems in executive functioning (Barkley, 2006; Castellanos & Tannock, 2002; Grabinger, Alpin & Ponappa-Brenner, 2008), in monitoring and inhibition skills (Schachar et al., 2004), self-regulation (Mullence & Klein, 2008) and social interactions (Barkley, 2006). This profile interacts with their cognitive profile and affects their school life and academic performance (Brand, 2002; DuPaul & Volpe, 2009). Thus, they have academic problems either in primary (Barkley, 2006) or in secondary school and home settings (Barkley, Fischer & Fletcher, 2006; Wolraigh et al., 2005).

Especially, students diagnosed as having ADHD are significantly less proficient than their peers in mathematics, an academic subject central in the core of the curriculums of almost every country of the world (Fletcher, 2005; Sousa, 2011; Zentall, 2007). Students with ADHD have serious problems managing basic numerical facts (Alontaga, 2012), sustaining their attention, especially in repetitive stimuli of mathematical assignments (Sims, Purpura & Lonigan, 2016; Zentall, Tom-Wright & Lee, 2013) and problem-solving, due to a memory or attention deficit (Rief, 2008). Researchers like Marjorie Montague (1996), Bouhouna (2011) and Miller and Mercer (1997), summarized students' with ADHD problems in mathematics, in four axes. First, their impairments in memory and strategies cause difficulties in mathematical basic facts, algorithms and representation recall. Second, their language and reading disorders, such as poor comprehension skills and low levels of literacy interact with ADHD symptoms of inattention and hyperactivity-impulsiveness (Hart, Petrill, Wilcutt, Thompson, Schatsneider, Deater-Deckard & Cutting, 2010). Third, their limited possession of problem-solving strategies and fourth, their vulnerability of motivation, that is self-esteem and affect problems (Bouhouna, 2011).

Their difficulties in mathematical performance, especially in computational fluency are well documented (Baroody, Purpura, Elland & Reid, 2014; Codding, Chan-Lannetta, Palmer & Lukito, 2009; Fox & Ghezzi, 2003; Jordan, Hanich & Kaplan, 2003; Lewandowski, Lovett, Parolin, Gordon & Codding, 2007; Smith et al, 2011; Poncy, Skinner & Jaspers, 2007). ADHD students demonstrate lower processing speed, math fluency, and achievement, no matter how much extended time given to them.

Computer Assisted Instruction (CAI) has being proposed as an effective instructional strategy for students diagnosed with ADHD. In a review of studies, DuPaul and Eckert (1998), suggested computer's use in classroom treatment of ADHD in school. Mathematical performance of students with ADHD was the focus of research in CAI in the early years. Kleiman, Humphrey, and Lindsay (1981) found that "*drill and practice*" in CAI context was way too efficient than "*paper and pencil one in tasks of mathematics for students diagnosed as having ADHD*". However, this study, had limitations, due to problems in participants' choose and information about their procedural knowledge (DuPaul & Eckert, 1998, p. 68).

Almost a decade after Kleiman and his colleagues' study, Ford, Poe, and Cox (1993) examined the efficacy of CAI programs in reading and mathematics of 21 students with ADHD. As they proposed, students' attentional skills promoted, when CAI used contrary to "drill and practice" and "tutorial" procedures. Nevertheless, they were limitations of this study, concerning no inter-observers of their conclusions after a period. In addition, Ford, Poe, and Cox (1993) did not arrive at a safe conclusion either the performance improvement was a result of task characteristics or other variables. This study was developed in a laboratory; alter to Kleinman, Humphrey and Lindsay's (1981) one.

Ota and DuPaul (2002) changed this point of view, as they examined the effectiveness of the software, in a game format (Math Blaster) of mathematics performance of a written seatwork condition at school. They worked with addition and subtraction (with or without regrouping), using correct digits per minute as an evaluation paradigm (Skinner, Belfiore, Mace, Williams-Wilson & Johns, 1997). They concluded that CAI had a positive effect on the active and passive engagement of these students with ADHD in completing tasks like addition and subtraction problems. Although higher performance in on-task behavior found, moderate improvement in mathematical performance emerged. Study limitations were present, as three participants were medicated and the generalization of the results is difficult.

In 2005, Mautone, DuPaul, and Jitendra evaluated the CAI impact on both mathematics performance and behavior of three, not medicated, second and third graders with ADHD. They found a significant improvement of their mathematics performance (on addition and subtraction), along with growth on on-task behavior using the same software (Math Blaster). The effect size computed was twice the size of previous studies (Kulik, Kulik & Bangert-Drowns, 1985), but different instructional use of CAI was implicated (Mautone, DuPaul and Jitendra, 2005, p. 308). The researchers' main finding was that the CAI approach had a higher acceptance among students and teachers than others did. However, concerns about the distraction of the whole classroom and stigmatization of those diagnosed with ADHD and used CAI emerged.

Smith, Marchand-Martella and Martella (2011) conducted another study concerning CAI's impact on the mathematical performance of students with ADHD. They used a software named "Rocket Math" (Crawford, 2009); in order to improve one first-grader's with ADHD addition performance. Assessment of his mathematical performance carried out with Curriculum-Based Measurement (CBM) (Shinn, 2002) in a single-case pre-test post-test non-experimental study. Smith, Marchand-Martella, and Martella concluded that generally, CAI had a positive effect on mathematical performance, as there was an increasing rate of correctly completed problems per minute. This finding was also common with Benett, Zental, French and Giorgetti-Bornucki's (2006) study. Mathematics was a background factor in nine students' with ADHD and seventeen non-disabled ones' performance. Although differences in mathematical performance of students' with ADHD and non-disabled ones' found, they did not reach a significant level.

In conclusion, studies supporting CAI effectiveness in the mathematics performance of ADHD students, were limited and had problems in the generalization of their conclusions. First, most of those studies did not compare CAI implementation gains of students with ADHD against their non-disabled classmates. Additionally, those students studied had in most of the times, serious mathematical deficits leading to moderate gains. Second, most of the studies did not investigate the maintenance of the performance gains of students, after the CAI implementation, being unable to generalize their conclusions. Third, the studies reviewed investigated CAI in caregiving and classroom educational settings. There was not any attempt studying CAI effectiveness in another important educational setting for ADHD students, their home.

Finally, although the literature suggested that ADHD subtypes have different levels of performance deficits, they were not took into account by the studies mentioned above. Due to all those reasons, along with that the only Greek study in the field (Solomonidou, Garagani-Areou & Zafiropoulou, 2004) supporting CAI effectiveness provided no data for gains in ADHD students' performance, lead to prepare and implement the study.

3. Purpose of the Study

This study examines the effectiveness of Computer – Assisted Instruction on mathematical operations of addition and subtraction performance of students diagnosed with ADHD and their non-disabled peers, in the context of an online Learning Management System. The mathematical operation performance of students was assessed right before, just after and after three months' time in "paper and pencil" and CAI conditions in order to determine the maintenance of intervention's effects.

In order to examine the effectiveness of CAI on the mathematical performance of students with ADHD, the study was divided into two parts with different research designs. The first one was the comparison between two groups, one of the students' with ADHD performance against non-disabled ones. An experimental 2 (groups) X 4 (conditions) nonequivalent-control group design was created as students were different by ADHD existence. Thus, eight experimental conditions were configured: a) ADHD students in "paper and pencil" pre-treatment condition, b) ADHD students in CAI condition, c) ADHD students in post-treatment "paper and pencil" condition, d) ADHD students in follow up condition, e) Non-disabled students in "paper and pencil" pre-treatment condition, f) Non-disabled students in CAI condition, g) Non-disabled students in post-treatment "paper and pencil" condition and h) Non-disabled students in follow up condition.

The second one was the within-subject examination of CAI effectiveness for students with ADHD. A single case study created. The baseline was a "paper and pencil" condition before the intervention. Treatment condition was Computer-Assisted Intervention, followed by a post-treatment "paper and pencil" condition. After three months of CAI condition implementation, a follow up computer-administered assessment of the maintenance of generalization conducted. Students with ADHD were to solve addition and subtraction with and without regrouping operations in a computer assessment environment.

The research questions of this study presented below:

1) Are there any differences in mathematical operation performance between students with ADHD and non-disabled students in three educational conditions (pre, CAI, post-treatment) and follow up single measure?
2) Are there any differences within subjects with ADHD in operation performance in pre, CAI, post- and follow up conditions?

3. Material and Methods

3.1 Participants

Six students with ADHD (students' characteristics presented in table 1) took part in this study, along with twelve non-disabled peers, consisted of the control group. The six ADHD participants selected after a procedure involving intensive contacts with schools, health care professionals and Facebook search. The searching condition criteria were a. ADHD diagnosis from a reliable public service, b. attending mainstream school, c. difficulties in mathematics, d. parental approval and e. computer and internet connection. Non-disabled participants were randomly selected from first and second graders attending a public elementary school in an urban region of Thessaloniki. The requirements for those students were a. no diagnosis of any kind of neurodevelopmental disorder, b. parental approval and c. computer and internet connection. The ADHD and non-disabled participants were a convenient sample consisted of a limitation of this study.

Table 1: Participants' with ADHD characteristics

	Sex	Age	ADHD Subtype[1]
1	Girl	9	ADHD-IA
2	Boy	9	ADHD-C
3	Boy	9	ADHD-C
4	Boy	7	ADHD-HI
5	Boy	8	ADHD-C
6	Boy	8	ADHD-IA

*ADHD-IA = Inattentive, ADHD-HI = Hyperactive-impulsive,
ADHD-C = Combined

As was noted above, twelve non-disabled students with no diagnosis of any neurodevelopmental or academic problem took part in the study, consisting of the control group. They were ten second-graders attending an urban mainstream school in Kalamaria, Thessaloniki and two non-disabled first graders from other urban non-disabled schools of the same region. More specifically, two boys and three girls were attending second grade whereas two boys were attending first grade.

3.2 Procedures

A. Baseline

Students with ADHD were solving worksheets with additions and subtractions, with or without regrouping at home. The directions to parents were to admeasure time while assignment solving and not interfering to worksheets' solution. Non-disabled students' worksheets administered in a group.

B. Intervention – CAI

In CAI condition, parents' presence was compulsory, protecting students from internet risks. After the parents' presence ensured by a numerical code, login to the Moodle (version 2.8) environment followed. Individual username and password had to be inserted in the individualized main board of the interface. The hyperlinks to sixteen lessons presented in this board organized in four week-periods (19th of May to 15th of June). Students were directed to complete four lessons, working every second day with one. Moodle was saving statistics and parameters of SCORM (version 1.2) interaction with the application. A researcher could access those data by entering as the administrator in Moodle – SCORM environment.

C. Post-treatment

In order to determine whether gains maintained, a post-treatment assessment administered. A similar to pre-test assessment was used. Students had to solve worksheets with addition and subtraction with and without regrouping exercises.

D. Follow up

A follow-up assessment developed for ADHD students to study performance improvement maintenance and generalization. Almost three months after CAI procedure involvement (from 1st of September to 7th) ADHD students were asked to complete a computer-assisted worksheet with additions and subtractions with or without regrouping in Moodle platform. In order to motivate students to work again, the session named "Final" and was intentionally associated with World Cup UEFA. Data acquired by SCORM interaction too.

3.3 Statistical Analyses

A. The Single Case versus Group Analysis

ADHD students are quite different compared to each other, so a comparison of them as a group versus the group of non-disabled students will reveal less and poorer data. In neuropsychology, often there is a need for comparing scores arising from a single case to scores from the general population in order to obtain more and richer data (Corballis, 2009). Crawford and Garthwaite (2002) proposed an adjusted t-test comparing a single case with the control sample. They adjusted the Sokal and Rohlf's (1995) modification of independent t-test to:

$$t = \frac{X_1 - \overline{X_2}}{S_2} \sqrt{\frac{N_2 + 1}{N_2}}$$

X1 is the single case's score, X2 is the average of the group's score, S2 is the standard deviation of the group's score and N2 number of group participants. As Crawford and his colleagues suggested this test does not assess whether the single case belongs in the population but whether the mean of single case distribution is different from the mean of the control group's (Crawford, Garthwaite & Ryan, 2011).

A significance test for every skill in every condition along with interval estimation of effect size and abnormality for a single case was computed (Crawford & Howell, 1998). Professor Crawford and his colleagues developed various software programs to administer those tests. The program used was DissocBayes_ES_CP, applying Bayesian criteria for dissociations in single-case studies. The scores of a case on two tasks compared to those of a control sample (Crawford, Garthwaite & Ryan, 2011).

B. Visual Graphic Analysis

Single case design studies have associated with the visual analysis of the graphic display of data (Kennedy, 2005). Especially studies that interpreting the effects of an intervention like this one are exemplary. Behaviors of each participant graphically illustrated by the session through all conditions (Lane & Gast, 2014). Sessions of various adjacent conditions graphed whereas each condition refers to sets of behavior (of specific variables).

As Gast and Hammond (2010) along with Lane, Wolery, Reichow, & Rogers (2007) suggest, the expectation is that data collected during baseline, will be stable and change in "therapeutic" direction during intervention condition, replicated at least three times across behaviors, settings or participants. Each participant's performance graphed and analyzed whether there were changes in a) trend, b) level and c) stability. Statistical analyses that were calculated were: a) standard mean difference, b) the percentage of non-overlapping data (PND) and c) regression (Riley-Tilman & Burns, 2009).

The standard mean difference calculated by the subtraction of the mean performance in baseline and in treatment condition divided by the standard deviation of performance in the baseline.

$$d = \frac{X_{treatment} - X_{baseline}}{SD_{baseline}}$$

Percentage of non-overlapping data is the calculation of non-overlap data points between baseline and intervention phases (Scruggs, Mastropieri & Castro, 1987). Although Allison and Gorman (1993) proposed regression as another valid tool for calculating effect sizes in single case designs, Scruggs and Mastropieri (1994) insisted that percentage of non-overlapping data is the most efficient tool to do so.

As for regression, Lane and Gast (2014) supported that use of this analysis in single case design has only one aim, to study the slopes in the graphic representation of data distribution.

C. Rate of Improvement

Rate of Improvement (ROI) is an index presenting a notion of the improvement achieved in intervention implementation. It is important in studying multi-tiered models when there is a need for progress monitoring of students. One of the most important uses of ROI is decision-making and goal setting procedures in instruction planning (Shapiro, 2008). Additionally, ROI's importance increased in visual inspection of slopes, when there are multiple interpretations of phenomena and whenever there is a need for explicit guidelines production.

Literature suggests that linear regression is the best practice to compute ROI along with "*last point minus first point approach*" (Shinn, Gleason & Tindal, 1989). This ROI supplemental approach computation computed by the formula

$$ROI = \frac{X_{Last} - X_{First}}{N_{of\ Weeks}}$$

4. Results and Discussion

Question 1: Differences between ADHD and Non-Disabled Students

In order to compare every single ADHD case against group of typical students' performance several t-tests using Crawford and Gartwaite's (2002) procedures for single-groups design. The t values, significance, mean differences and estimations of percentage of typical population falling below single case's score presented to the table 2 below, each for every ADHD student of the sample.

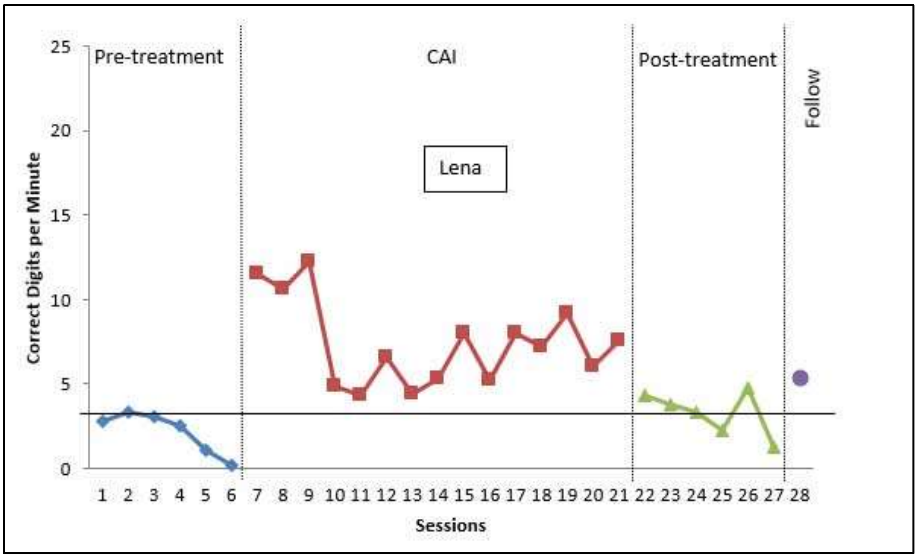
Table 2: Differences in Correct Digits per Minute between students with ADHD and the non-disabled in four conditions

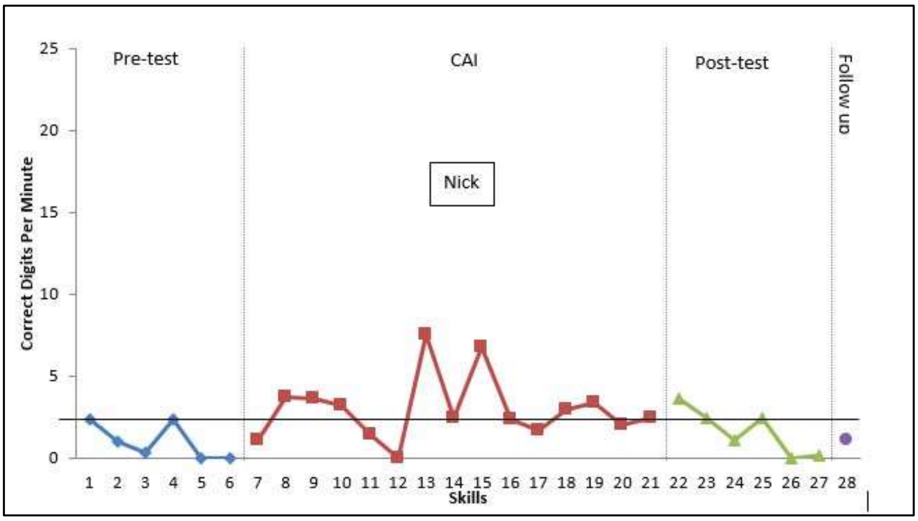
	Lena					**Nick**				
Cond.[a]	**t**	**Sig**[b]	**Mean Diff.**	**ES**[c]	**Estim**[d] **%**	**t**	**Sig**[b]	**Mean Diff.**	**ES**[c]	**Estim**[d] **%**
pre	-1.812	0.097	0.93	-1.886	4.86	**-3.937**	**0.002**	**2.02**	**-4.097**	**0.11**
CAI	0.137	0.894	-0,13	0.142	55.31	**-4.541**	**0.001**	**4.32**	**-4.726**	**0.04**
post	-1.459	0.173	1.52	-1.518	8.63	-2.899	0.145	3.02	-3.017	0.72
FU[e]	0.869	0.404	-0.7	0.904	79.83	**-4.543**	**0.001**	**3.66**	**-4.729**	**0.04**
	John					**George**				
pre	**-4.365**	**0.001**	**2.99**	**-4.544**	**0.06**	**-5.203**	**0.0003**	**2.67**	**-5.416**	**0.02**
CAI	**-3.437**	**0.006**	**3.27**	**-3.578**	**0.28**	**-2.460**	**0.032**	**2.34**	**-2.560**	**1.58**
post	**-3.311**	**0.007**	**3.45**	**-3.447**	**0.35**	**-3.897**	**0.003**	**4.06**	**-4.056**	**0.13**
FU[e]	**-3.687**	**0.004**	**2.97**	**-3.837**	**0.18**	**-4.605**	**0.001**	**3.71**	**-4.793**	**0.04**
	Kostas					**Jim**				
pre	-0.546	0.596	0.28	-0.568	29.81	-0.195	0.849	0.10	-0.203	42.45
CAI	**-2.859**	**0.016**	**2.78**	**-2.976**	**0.78**	**2.134**	**0.056**	**-2.03**	**2.221**	**97.19**
post	-0.326	0.750	0.34	-0.340	37.52	-0.154	0.880	0.16	-0.160	44.04
FU[e]	-0.571	0.579	0.46	-0.594	28.97	-0.546	0.596	0.44	-0.568	29.79

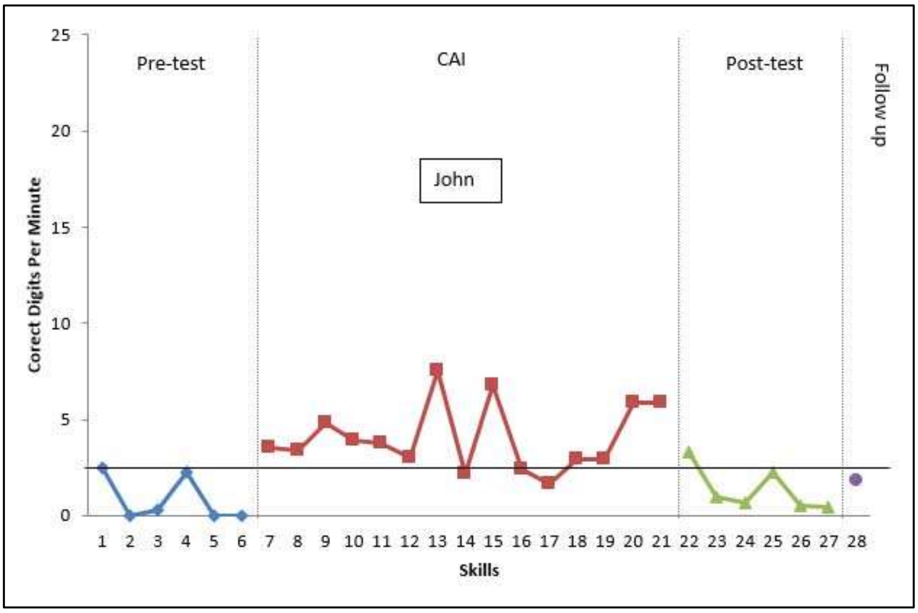
a=Condition, b=Significance, c=Effect Size, d=Estimation, e=Follow Up Condition.

Question 2: Differences within ADHD Students

All six participants diagnosed with ADHD increased their mathematical operations performance from pre- to CAI intervention face. There was a slight or bigger decrease incorrect digit per minute performance between CAI and post-assessment face, but there was an improvement from baseline (pre-assessment). This view remained the same after three months period, in follow up condition. Mean performance, standard deviation of students' performance, along with math operations fluency in every condition data, presented in figure 1 below.


Pre-treatment
CAI
Post-treatment
Follow
Lena
Correct Digits per Minute
Sessions


Pre-test
CAI
Post-test
Follow up
Nick
Correct Digits Per Minute
Skills


Pre-test
CAI
Post-test
Follow up
John
Corect Digits Per Minute
Skills

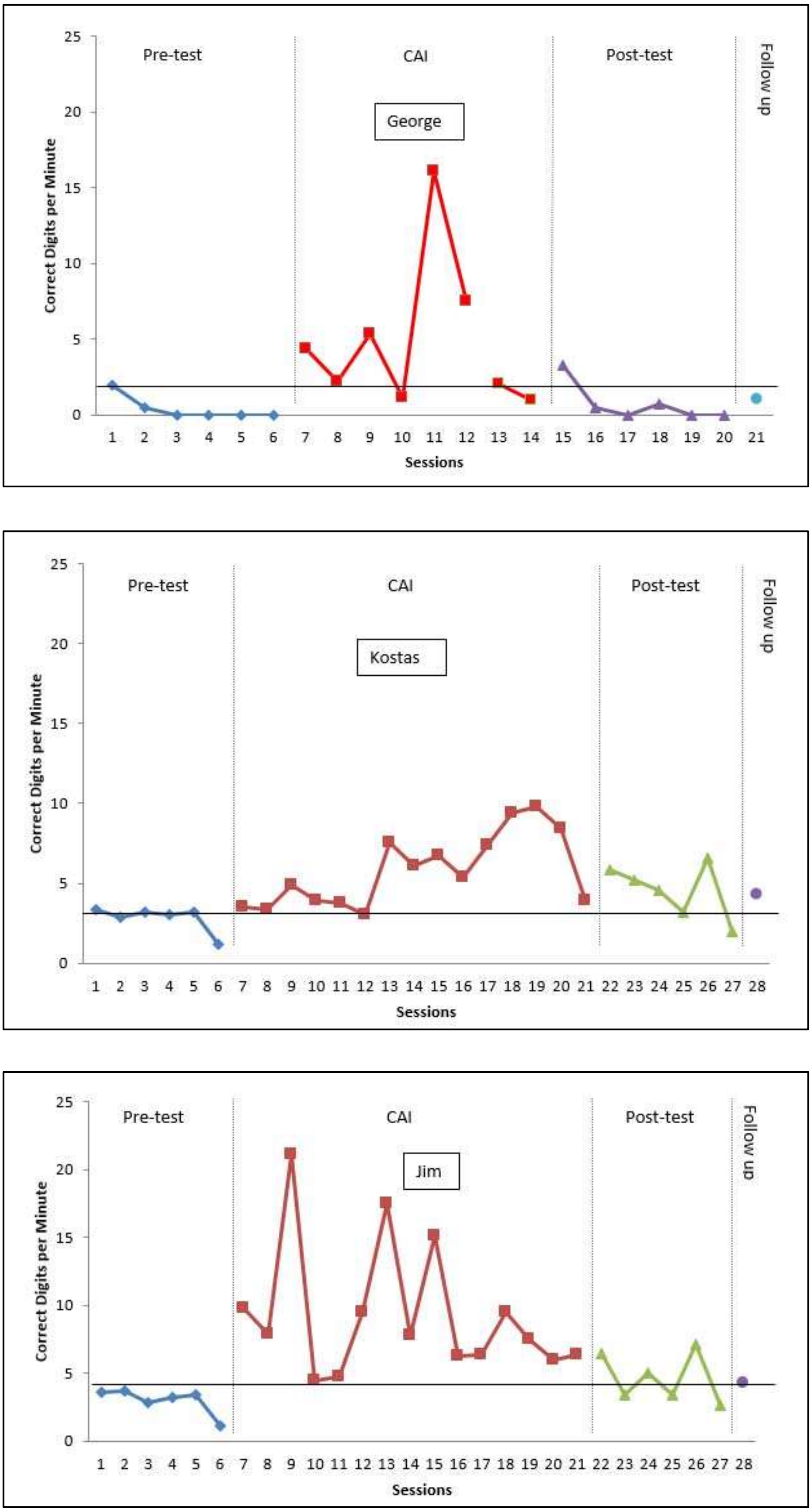


Figure 1: Mathematical operation fluency data for all participants in three conditions and follow up

Studying the trends of graphical representation, with standard mean differences, high effect sizes found between pre-treatment and CAI conditions for all six students ($M_{pre\text{-}CAI} = 4.23 > 0.8$). A change of trend between CAI and post-treatment conditions with high effect sizes was also revealed ($M_{CAI\text{-}post} = 1.34 > 0.8$) implying a decrease in performance. Finally, a high effect size found between pre- and post-treatment of "paper and pencil" performance ($M_{pre\text{-}post} = 1.36 > 0.8$) suggesting that students had some stable achievement gains. Mixed data for CAI efficacy found when analyzing the non-overlapping data. CAI found to be a highly effective intervention for Lena, Kostas, and Jim, moderately for John and George, while it was minimally effective for Nick. The results for effect sizes and non-overlapping data analysis presented in table 3.

Table 3: Mean differences (effect sizes) in three conditions,
Non-Overlapping Data Percentage and treatment effectiveness

	Mean differences[1]			NOD	
Student	$\mathbf{d_{pre\text{-}CAI}}$	$\mathbf{d_{CAI\text{-}post}}$	$\mathbf{d_{pre\text{-}post}}$	**NODP**	**Effectiveness[2]**
Lena	4.66 ↑	1.67 ↓	-1.02 ↑	100%	Highly
Nick	1.78 ↑	0.61 –	0.69 –	67%	Minimally
John	2.94 ↑	1.58 ↓	-1.58 ↑	80%	Moderately
George	6.40 ↑	0.89 ↓	0.49 –	75%	Moderately
Kostas	2.31 ↑	2.31 ↓	-2.44 ↑	93%	Highly
Jim	7.26 ↑	0.99 ↓	-1.92 ↑	100%	Highly

1 High Effect size = d > 0.8
2 Highly effective, NODP > 90%, minimally effective, NODP < 70%

The linear regression coefficients presented in table 5, indicated that an increasing trend in CAI condition slope followed by a rather stable trend of slopes in post-treatment. The high rate of performance improvement ($M_{ROI} = 0.83 > 0.5$) for six students diagnosed with ADHD, was at the "ambitious" level (Fuchs et al., 1998), apart from Nick's performance which was in "realistic" level (table 4).

Table 4: Linear regression coefficients for students' performance (CDpM[1])
for three conditions, ROI and performance levels

	Linear Regression Coefficients			ROI[2]	
Student	**Pre-**	**CAI**	**Post-**	**ROI**	**Levels[3]**
Lena	.525	.967	.741	1.27	Ambitious
Nick	.566	.892	.534	0.35	Realistic
John	.385	.750	.643	0.69	Ambitious
George	.652	.952	.620	0.50	Ambitious
Kostas	.209	.782	.586	1.15	Ambitious
Jim	.041	.503	.223	1.00	Ambitious

1 CDpM = Correct Digits per Minute (Skinner, Belfiore, Mace, Williams-Wilson & Johns, 1997)
2 ROI = Rate Of Improvement (Shinn, Gleason & Tindal, 1989).
3 Fuchs, Fuchs Hamlett, Walz & Germann (1993).
Ambitious level = ROI<0.50 Realistic level = 0.30<ROI<0.50

5. Discussion

The aim of this study was to examine the effectiveness of Computer – Assisted Instruction (CAI) on mathematical operations of addition and subtraction performance primarily of students diagnosed as having Attention Deficit – Hyperactivity Disorder (ADHD) and secondarily their non-disabled peers in an online context. The online context was the stable environment of Moodle, a Learning Management System (LMS), where a math software in game-format was running. As previous studies have suggested, such a software lead to increased time of engagement and motivation to students with ADHD performance (Ford et al., 1993; Ota & DuPaul, 2002). Additionally, LMS provided teachers an immediate and reliable connection to their homework achievement and results. That is, teachers could not only give feedback, but also monitor their students' with ADHD homework as well, (Mautone et al., 2005). Studies in CAI preceded, examined its effectiveness in the laboratory (Ford, Poe, & Cox, 1993; Kleiman, Humphrey, & Lindsay, 1981) or educational – school settings (Mautone, DuPaul & Jitendra, 2005; Ota & DuPaul, 2002). This study extended our view of students' with ADHD educational use of computers in a setting that they live most of their time, their homes. The study of an educational treatment, taking place at home, supervised by parents, designed, actually administered and monitored by the teacher, was a quite enlightening effort. The opportunity of guiding homework and getting direct, reliable and immediate feedback from ADHD students' performance provides teachers with a significant tool for organizing and implementing individualized instruction.

Although the ideal setting for teaching students with ADHD is the mainstream classroom, previously conducted studies for CAI effectiveness in the classroom presented various problems. First, the computer use by ADHD students could be a source of distraction for the rest of the students in the classroom. Teachers in Mautone et al. (2005) study actually forced to apply CAI treatment in other settings (e.g. computer's lab) or other time (e.g. lunchtime) in order to minimize distractions. However, this was not actually an active and inclusive educational setting. Second, especially for students in late elementary school grades, there is always the concern of possible stigmatization. Their peers segregated students with ADHD, working with other material in the computer than the common one, as disabled.

The results of the present study suggest that CAI is an effective intervention for students with and without ADHD in mathematics. CAI has a differentiating but positive impact on the mathematics fluency performance in addition and subtraction with and without regrouping. The study extended the findings of the previous ones as it examined CAI effectiveness not only in the mathematics-disabled students with ADHD but also to non-disabled ones. Only Solomonidou, Garagouni-Areou and Zafiropoulou (2004) studied CAI in non-disabled students also, along with those with ADHD, but presented no quantitative data.

Generally, large effect sizes noted, referring to all students. Kulik, Kulik, and Bangert – Drowns (1985) in a meta-analysis of 28 studies of CAI effectiveness found an average effect size of d = 0.47, while in their other meta-analysis of 248 studies (Kulik & Kulik, 1991) the average effect size was d = 0.30. The effect size of this study was d = 0.99 similar to other studies with ADHD students like Mautone et al. (2005) which effect size almost exceeds d = 1.00. A possible explanation could be the educational manipulation of CAI features (feedback, visual and auditory cues, animation, curricular adaptations, etc.), along with the actual academic subject of mathematics, found more suitable to CAI intervention (Raggi & Chronis, 2006).

Another way that this study extended the findings of previous studies was that there were data from a post-treatment "paper and pencil" condition, right after the last lesson of CAI setting. The purpose was to examine whether there was a trend of maintenance in the performance of students with and without ADHD. Additionally, after a three-month period (summertime vacation) there was a follow-up measure of CAI gains in math performance maintenance. Unfortunately, programming problems referring to Articulate® Storyline, limited follow up procedure to one global single measurement of Correct Digits per Minute.

The first research question was whether there were any differences in mathematical operation performance between students with ADHD and non-disabled students in three educational conditions (pre-, CAI, post-treatment) and a follow up single measure. The answer to this question proved to be a complex one. Students with ADHD in a high proportion (30% - 40%) are at risk of exhibiting mathematical learning disabilities, having serious problems with managing the basic facts and applying mathematical operations like addition and subtraction (Allontaga, 2012; Zentall, Smith, Lee & Wieczoek, 1994).

Three of the students with ADHD in our sample face major problems in mathematical performance. They encountered problems in managing basic mathematical facts, addition and subtraction implementation, along with difficulties in realizing the concepts of numbers. Those students found to have significantly limited mathematics performance than their non-disabled peers in all research conditions. There were striking differences to non-disabled students in all conditions, before treatment, during CAI condition, right after CAI and follow up.

On the contrary, the other three students with ADHD presented a rather typical profile in mathematics, nearly the same with their classmates who were non-disabled. Two of those students were mostly inattentive, and one combined type. As Zentall and Ferkis (1993) suggested the impaired computational skills of students with ADHD may be the result of impaired sustained attention. Although there is no consensus, researchers proposed that the mathematical disability of students with ADHD could be associated with the inattentive type of the disorder (Marshall, Hynd, Handweek & Hall, 1997; Mastropieri, Scruggs & Chung, 1998). This profile fits in one of the ADHD-IA students of our sample, as her problems were clearly associated with her inattentiveness. However, the other student with ADHD-IA (Predominantly Inattentive type) presented a more effective profile, also similar to non-disabled ones. This discrepancy was quite difficult to explain in this study. It could be due either to specific students' abilities and deficiencies or to what Benedetto-Nasho and Tannock (1999) suggested. They posed that problems in working memory and not inattention are the causes of computational problems in students with ADHD. This conclusion could explain the same performance levels, quite similar to non-disabled, that the third non-math disabled ADHD-C (Combined type) student of the sample, presented.

The most common finding for the three students with ADHD with minor mathematical learning problems was that their performance, when instructed with the assistance of computers, was quite similar to non-disabled students' one. Students with ADHD had the opportunity to practice their skills in addition and subtraction, regardless of the disorder's subtype. The immediate feedback of software also motivated them to compensate minor problem, in their procedural and conditional knowledge of performing mathematical operations in a fluent way. We could assume that CAI is likely to provide frequent, immediate reinforcement for those students, stimulating them to "bridge" attentional gaps, as ADHD-IA students of the sample had the higher Rate of Improvement (DuPaul & Eckert, 1998; Mautone et al., 2005).

The second research question whether there were differences within subjects with ADHD in operation performance in pre-, CAI, post- and follow up conditions. CAI found to be effective for all students with ADHD. Referring to Rate of Improvement (ROI) data, all students with ADHD with or without major mathematical problems, along with non-disabled students increased their performance in computational fluency from "paper and pencil" condition to CAI one. The ROI computations vary from 1.27 Correct Digits per Week of students with ADHD with minor problems to 0.35 Correct Digits per Week of students with major computation fluency problems. Non-disabled students' ROI was 1.05 Correct Digits per Week, in the same or lower levels than students with ADHD with minor problems. Fuchs and her colleagues (1993, 1994) established criteria for determining the outcomes of students in various mainstream education settings. Those criteria were established and used in Curriculum-Based Measurement (CBM) context. According to Fuchs, computation fluency for 1st to 3rd grades, a "realistic" weekly growth could be 0.30 Correct Digits per Week and an "ambitious" one, 0.50 Correct Digits per Week. Based on these criteria, the improvement of all students with ADHD, except Nick's, was in the level of "ambitious". Nick's improvement because of CAI condition was 0.35 Correct Digits per Week, exceeding the threshold of "realistic" improvement (0.30 Correct Digits per Week).

However, there were significant features implying that there was a differentiated impact of computers' use in every single ADHD student, as they have different academic profiles and traits. This study supports prima facie, what Lamminmaeki and his colleagues (1995) noted. That is, inattentive students are not more impaired in mathematics compared to those with hyperactivity or/and impulsiveness problems. Of course, there are some concerns about some features as those studies used neuropsychological tasks in order to study ADHD subtypes differences (Lamminmaeki et al., 1995; Nigg, Blaskey, Huang-Pollock & Rappley, 2002). Matching Lamminmaeki's findings and doubts about inattentive students' severe problems, with an educational study like this, is a controversial but valid concern.

Another important finding was that, contrary to CAI effectiveness literature, an adaptation of instructional level to student's level. Studies indicate that students with ADHD increased their academic performance when tasks match their individual academic levels and when performance results in frequent and consistent consequences (Brown, 2005; Clarfield & Stoner, 2005; DuPaul & Stoner, 2003). However, those studies were not referring to severe academic disabled ADHD students like George, but to students with mild and moderate problems.

Regardless of George's data, adaptations and differentiation of instruction have to be done either "watering down" or "watering up" student's curriculum (Sousa & Tomlinson, 2011). Our concern is that "watering up", enriching student's curriculum could cause instructional problems as will increase the length of instruction sessions and consequently reduce on-task behavior or impulsivity. On the other hand, "watering down" student's curriculum could segment knowledge to a large number of instructional curriculum pieces and cause boredom to ADHD students. Differentiation and adaptation of students' curricula are a very serious educational demanding action, requiring careful planning, thoughtful implementation, and continuous monitoring. Making comparisons between ADHD students one could suggest that there were differentiated performance gains and proportion of maintenance performance among them. Three ADHD students with minor academic problems had higher gains and CAI proved to be a highly effective instructional strategy for them. Additionally, a great proportion of these gains maintained through time, even three months after the CAI treatment. On contrary ADHD students with major mathematical problems revealed lower gains as CAI appeared to be moderately or minimally effective. Of course, this is huge attainment for those severely learning-disabled students, but their traits prevent them from maintaining those gains through time. Some of them were not present even little time after the CAI condition completion.

Apart from the educational implications for this finding, one could suggest that the "Matthew" effect is present in ADHD too, in a more distinct form. "Matthew effects in education refer to the rich-get-richer / poor-get-poorer consequences that ensue for students who are stronger versus weaker achievers at the outset of schooling, and whose subsequent academic progress is thus enhanced or impeded in a self-reinforcing way by differential experiences that are triggered by the initial success or failure." (Scarborough & Parker, 2003, p. 48) Eventually, students with ADHD with severe academic problems get "poorer" through schooling, even if they have some temporal gains. They cannot maintain those gains, returning to their impaired and deficient performance level quite quickly. On the contrary, ADHD students with minor academic problems or/and being in a supportive environment get "richer" and have gained from interventions like CAI. Their characteristic is that can maintain those gains and capitalize their potential. If our finding is valid, as most of the previous studies only imply this without citing it explicitly (Mautone et al., 2005; Ota & Dupaul, 2002), it has to be considered in developing special education and compensatory curricula of students with ADHD. Teachers' concern has to be the construction of a solid, scaffolding and motivating program in a continuum of instructional goals, strategies, and tasks.

5.1 Limitations

The first limitation of the present study is the limited number of students took part. ADHD students and non-disabled ones were only 18 in sum, a very modest sample to generalize conclusions. Additionally, follow up could not give us more information as due to a programming problem LMS, data about the specific time that the student spent on every single task, could not be gained. Adaptation of goals and tasks implemented in only one participant, while others could benefit from adapting CAI condition to their academic level. There was no information about students' proficiency in using and controlling working with mathematical software. Auditory cues' speed or using more colors and animations should improve software, to help students' engagement. Moreover, there has to be more typing in working with computational operations, and less "drag and drop" tasks. Mathematical computation fluency limited only in addition and subtraction, showing an elementary picture of students' abilities and performance. Operations of higher difficulty like multiplication or division or even problem solving would pose more academic obstacles to all ADHD students. There was no data collection of students' off-task behaviors. That could be very interesting in order to make inferences about the way children actually react to computers and Computer-Assisted Instruction.

6. Recommendations

This study has various educational implications. First, it extends previous studies on CAI effectiveness in various settings. Home as an educational setting for students with ADHD examined as a reliable, non-threatening, and familiar with limited distraction environment, of homeworking. The mainstream classroom is, of course, the best educational setting, but home with the help of online CAI could set up an efficient place of compensatory instruction, with parent and teacher interaction. Teachers will have to plan and monitor the student's homework while parents will supervise it. Parents – teachers' interactions delimited and placed in a context of collaboration within the boundaries. As for monitoring of general and mathematical ADHD student's progress, the study highlighted the effectiveness apart from CAI and the use of Curriculum-Based Measurement (CBM) as a useful tool for student's improvement tracking. Data attained in this study's assessment mode could help decision making in a Response to Instruction (RTI) context (McMaster, Fuchs, Fuchs & Compton, 2005). In the last two years, there has been set up a special educational needs detection web in Greece, working in the context of RTI. Children with problems identified as being at risk, instructed in a differentiated mode and afterward, specialists decide whether they need to nominate them for diagnosis in specific centers. CBM along with visual graphic analysis, used in this study are tools for deciding whether a student responded to intervention.

7. Conclusion

In sum, CAI seems to be an effective intervention in order to improve mathematical computation performance in students with ADHD (Botsas & Grouios, 2017). The use of game format mathematical software with visual and auditory cues, immediate feedback and no excessive animations, implemented through online LMS context, led to performance gains in addition and subtraction tasks for all ADHD students. Although there were at least CAI minimally effective data, there were differentiated maintenance performance gains. CAI condition implemented at home setting extended previous studies' findings.

References

Allison, D. B. & Gorman, B. S. (1993). Calculating effect sizes for meta-analysis: The case of the single case. *Behavior Research and Therapy, 31,* 621-631. doi: 10.1016/0005-7967(93)90115-B.

Allontaga, J. V. Q. (2012). A computer-assisted instruction module on enhancing numeracy skills of preschoolers with Attention-Deficit Hyperactivity Disorder. International Journal of Information Technology and Business Management, 2(1), 1-15.

American Psychiatric Association (2013). Diagnostic and Statistical Manual of Mental Disorders. Fifth edition (DSM-V). Washington, DC: American Psychiatric Pub.

Barkley, R. A. (2006). Attention – Deficit Hyperactivity Disorder. A handbook for diagnosis and treatment, 3rd ed. New York, NY: The Guilford Press.

Barkley, R. A., Fischer, M., Smallish, L. & Fletcher, K. (2006). Young adult outcome of hyperactive children: Adaptive functioning in major life activities. Journal of American Academy of Child and Adolescence Psychiatry, 45(2), 192-202. doi: 10.1097/01.chi.0000189134.97436.e2.

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. Journal of Abnormal Psychology, 111(2), 279-289. doi: 10.1037/0021-843X.111.2.279.

Baroody, A. J., Purpura, D. J., Eiland, M. D. & Reid, E. E. (2014). Fostering first graders' fluency with basic subtraction and larger addition combination via computer-assisted instruction, Cognition and Instruction, 32(2), 159-197. doi: 10.1080/07370008.2014.887084.

Barron, K., Evans, S., Baranik, L., Serpell, Z., & Buvinger, E. (2006). Achievement goals of students with ADHD. Learning Disability Quarterly, 29 (3), 137-158. doi: 10.2307/30035504.

Benedetto-Nasho, E. & Tannock, R. (1999). Math computation, error patterns and stimulant effects in children with Attention Deficit Hyperactivity Disorder. Journal of Attention Disorders, 3(3), 121–134. doi: 10.1177/108705479900300301.

Bennett, D. E., Zentall, S. S., French, B. F. & Giorgetti-Borucki, K. (2006). The effects of computer-administered choice on students with and without characteristics of Attention-Deficit/Hyperactivity Disorder. Behavioral Disorders, 31(2), 189-203. doi: 10.1177/019874290603100201.

Botsas, G., & Grouios, G. (2017). Computer Assisted Instruction of Students with ADHD and Academic Performance: A Brief Review of Studies Conducted Between 1993 and 2016, and Comments. European Journal of Special Education Research. doi: 10.5281/zenodo.1058974.

Bouhouna, S. (2011). Computer use and motivation in mathematical problem-solving tasks: The case of children with Attention-Deficit Hyperactivity Disorder. Unpublished thesis, Thessaloniki, GR: School of Psychology, Aristotle's University of Thessaloniki [in Greek].

Brand, S. (2002). Learning styles of students with attention deficit hyperactivity disorder: who are they and how can we teach them? Clearing House, 75, 268-274. doi: 10.1080/00098650209603953.

Brown, T. (2005). Attention Deficit Disorder. The unfocused in children and adults. London: Yale University Press.

Castellanos, F. X. & Tannock, R. (2002). Neuroscience of attention deficit / hyperactivity disorder: The search for endorphenotypes, Nature Reviews Neuroscience, 3, 617-328. doi: 10.1038/nrn896.

Clarfield, J. & Stoner, G. (2005). The effects of computerized reading instruction on the academic performance of students identified with ADHD, School Psychology Review, 34(2), 246 – 254.

Codding, R. S., Chan-lannetta, L., Palmer, M., & Lukito, G. (2009b). Examining a classwide application of cover-copy-compare with and without goal setting to enhance mathematics fluency. School Psychology Quarterly, 24(3), 173–185. doi: 10.1037/a0017192.

Corballis, M.C. (2009). Comparing single case with a control sample. Refinements and extensions. Neuropsychologia, 47, 2687-2689. doi: 10.1016/j.neuropsychologia.2009.04.007.

Crawford, D. (2009). Rocket Math. Baltimore, MD: R&D Instructional Solutions.

Crawford, J. R. & Howell, D. C. (1998). Comparing an individual's test score against norms derived from small samples. The Clinical Neuropsychologist, 12, 482-486. doi: 10.1076/clin.12.4.482.7241.

Crawford, J. R., & Garthwaite, P. H. (2002). Investigation of the single case in neuropsychology: Confidence limits on the abnormality of test scores and test score differences. Neuropsychologia, 40, 1196-1208. doi: 10.1016/S0028-3932(01)00224-X.

Crawford, J. R., Garthwaite, P. H. & Ryan, K. (2011). Comparing a single case to a control sample. Testing for neuropsychological deficits and dissociations in the presence of covariates. Cortex, 47, 1166-1778. doi: 10.1016/j.cortex.2011.02.017.

Daley, D., & Birchwood, J. (2010). ADHD and academic performance: why does ADHD impact on academic performance and what can be done to support ADHD children in the classroom?. Child: care, health and development, 36(4), 455-464. doi: 10.1111/j.1365-2214.2009.01046.x.

DuPaul, G. J. & Eckert, T. L. (1998). Academic interventions for students with Attention-Deficit/Hyperactivity Disorder: A review of the literature, Reading & Writing Quarterly: Overcoming Learning Difficulties, 14(1), 59-82. doi: 10.1080/1057356980140104.

DuPaul, G. J., & Stoner, G. (2003). ADHD in the schools: Assessment and intervention strategies (2nd ed.). New York: Guilford Press.

DuPaul, G. J., & Volpe, R. J. (2009). ADHD and learning disabilities: Research findings and clinical implications. Current Attention Disorders Reports, 1(4), 152-155. doi: 10.1007/s12618-009-0021-4.

Fletcher, J. M. (2005). Predicting math outcomes: Reading predictors and comorbidity, Journal of Learning Disabilities, 38(4), 308-312. doi: 10.1177/00222194050380040501.

Ford, M. J., Poe, V., & Cox, J. (1993). Attending behaviors of ADHD children in math and reading using various types of software. Journal of Computing in Childhood Education, 4, 183–196.

Fox, E. J., & Ghezzi, P. M. (2003). Effects of computer-based fluency training on concept formation. Journal of Behavioral Education, 12(1), 1-21. doi: 10.1023/A:1022373304577.

Fuchs, L. S., Fuchs, D., Hamlett, C. L., Thompson, A., Roberts, P. H., Kubek, P., & Stecker, P. (1994). Technical features of a mathematics concepts and applications curriculum-based measurement system. Diagnostique, 19, 23-49. doi: 10.1177/073724779401900403.

Fuchs, L. S., Fuchs, D., Hamlett. C. L., Walz, L. & Germann, G. (1993). Formative evaluation of academic progress: How much growth can we expect? School Psychology Review, 22(1), 27 – 48.

Gast, D. L., & Hammond, D. (2010). Withdrawal and reversal designs. In D. L. Gast (Ed.), Single subject research methodology in behavioral sciences (pp. 234– 275). New York, NY: Routledge.

Grabinger, S. R., Aplin, C. & Ponnappa-Brenner, G. (2008). Supporting learners with cognitive impairments in online environments. TechTrends, 52(1), 63-69. doi: 10.10007/s11528-008-0114-4.

Hart, S. A., Petrill, S. A., Willcutt, E., Thompson, L. A., Schatschneider, C., Deater-Deckard, K., & Cutting, L. E. (2010). Exploring how symptoms of attention-deficit/hyperactivity disorder are related to reading and mathematics performance: General genes, general environments. Psychological Science, 21(11), 1708-1715. doi: 10.1177/0956797610386617.

Jordan, N. C., Hanich, L. B. & Kaplan, D. (2003). Arithmetic fact mastery in young children: A longitudinal investigation. Journal of Experimental Child Psychology, 85, 103–119. Doi: 10.1016/S0022-0965(03)00032-8.

Kalantzi – Azizi, A., Aggeli, K. & Efstathiou, G. (2005). The Greek version of ADHD rating scale-IV of DuPaul, G.J., Power, T.J., Anastopoulos, A.D., Reid, R., Athens, GR: Ellinika Grammata [In Greek].

Kaplan, B. J. (2000). The IQs of children with ADHD are normally distributed. Journal of Learning Abilities, 33,(5) 425-423. doi: 10.1177/002221940003300503.

Kennedy, C. H. (2005). Single-case designs for educational research. Boston, MA: Allyn & Bacon.

Kleiman, G., Humphrey, M., & Lindsay, P. H. (1981). Microcomputers and hyperactive children. Creative Computing, 7, 93-94.

Kulik, C-L., C & Kulik, J. A. (1991). Effectiveness of Computer-Based Instruction: An updated analysis. Computers in Human Behavior, 7, 75-94. doi: 10.1016/0747-5632(91)90030-5.

Kulik, J. A., Kulik, C-L, C. & Bangert – Drowns, R. L. (1985). Effectiveness of Computer-Based Education in Elementary Schools. Computers in Human Behavior, 1, 59-74. doi: 10.1016/0747-5632(85)90007-X.

Lamminmaeki, T., Ahonen, T., Naerhi, V., Lyytinen, H. & Todd de Barra, H. (1995). Attention deficit hyperactivity disorder subtypes: Are there differences in academic problems? Developmental Neuropsychology, 11, 297–310. doi: 10.1080/87565649509540621.

Lane, J. D. & Gast, D. L. (2014). Visual analysis in single case experimental design studies: Brief review and guidelines, Neuropsychological Rehabilitation: An International Journal, 24(3-4), 445-463. doi: 10.1080/09602011.2013.815636.

Lane, K., Wolery, M., Reichow, B., & Rogers, L. (2007). Describing baseline conditions: Suggestions for study reports. Journal of Behavioral Education, 16, 224–234. doi: 10.1007/s10864-006-9036-4.

Law 3699/2008 (2008). Special education of disabled and/or special educational needs, FEK 199/v. A'/2-10-2008.

Law 4186/2013 (2013). Restructuring Secondary Education, FEK 193/v. A'/17-09-2013.

Lewandowki, L.J., Lovett, B.J., Parolin, R., Gordon, M. & Codding, R.S. (2007). Extended time accommodations and the mathematics performance of students with and without ADHD, Journal of Psychoeducational Assessment, 25(1), 17-28. doi: 10.1177/0734282906291961.

Marshall, R. M, Hynd, G. W., Handwerk, M. J , & Hall, J. (1997). Academic underachievement in ADHD subtypes. Journal of Learning Disabilities, 30(6), 635-642. doi: 10.1177/002221949703000607.

Mastropieri, M. A., Scruggs, T. E., & Chung, S. (1998). Instructional interventions for students with mathematics learning disabilities. In B. Y. L. Wong (Ed.), Learning about learning disabilities (2nd ed., pp. 425–451). San Diego: Academic Press.

Mautone, J. A., DuPaul, G. J. & Jitendra, A. K. (2005). The effects of Computer Assisted Instruction on the mathematics performance and classroom behavior of children with ADHD. Journal of Attention Disorders, 9, 301-311. doi: 10.1177/1087054705278832.

McMaster, K. L., Fuchs, D., Fuchs, S. L. & Compton, D.L. (2005). Responding to nonresponders: An experimental field trial of identification and intervention methods. Exceptional Children, 71(4), 445 – 463. doi: 10.1177/001440290507100404.

Miller, S. P., & Mercer, C. D. (1997). Educational aspects of mathematics disabilities. Journal of Learning Disabilities, 30, 47–56. doi: 10.1177/002221949703000104.

Montague, M. (1996). Student perception, mathematical problem solving, and learning disabilities. Remedial and Special Education, 18(1), 46–53. doi: 10.1177/074193259701800108.

Moodle (version 2.8) [Computer software]. Moodle Pty Ltd.

Mullane, J. C. & Klein, R. M. (2008). Visual search by children with and without ADHD. Journal of Attention Disorders, 12(1), 44-53. doi: 10.1177/1087054707305116.

Nigg, J. T., Blaskey, M. A., Huang-Pollock, M. A., & Rappley, M. D. (2002). Neuropsychological executive functions and DSM-IV ADHD subtypes. Journal of the American Academy of Child and Adolescent Psychiatry, 41, 59–66. doi: 10.1097/00004583-200201000-00012.

Ota, K. R. & DuPaul, G. J. (2002). Task engagement and mathematics performance in children with Attention – Deficit Hyperactive Disorder: Effects of supplemental computer instruction, School Psychology Quarterly, 17(3), 242 – 257. doi: 10.1521/scpq.17.3.242.20881.

Polanczyk, G., De Lima, M. S., Horta, B. L., Biederman, J. & Rohle, L. A. (2007). The worldwide prevalence of ADHD: a systematic review and metaregression analysis. American Journal of Psychiatry, 164(6), 942-948. doi: 10.1176/ajp.2007.146.6.942.

Poncy, B. C., Skinner, C. H., & Jaspers, K. E. (2007). Evaluating and comparing interventions designed to enhance math fact accuracy and fluency: Cover, copy, and compare versus taped problems. Journal of Behavioral Education, 16, 27-37. doi: 10.1007/s10864-006-9025-7.

Raggi, V. L. & Chronis, A. M. (2006). Intervention to address the academic impairment of children and adolescents with ADHD, Clinical Child and Family Psychology Review, 9(2), 85-111. doi: 10.1007/s10567-006-0006-0.

Rief, S. (2008). The ADD/ADHD Checklist A Practical Reference for Parents & Teachers. San Francisco, CA: Jossey – Bass.

Riley-Tillman, T. C. & Burns, M. K. (2009). Evaluating Educational Interventions: Single-Case Design for Measuring Response to Intervention. New York, NY: The Guilford Press.

Scarborough, H. S. & Parker, J. D. (2003). Matthew effects in children with Learning Disabilities: Development of reading, IQ and psychosocial problems from grade 2 to grade 8. Annals of Dyslexia, 53, 47 – 71. doi: 10.1007/s11881-003-0004-6.

Schachar, R. J., Chen, S., Logan, G. D., Ornstein, T. J., Crosbie, J., Ickowicz, A. & Pakulak, A. (2004). Evidence for an error-monitoring deficit in Attention Deficit/Hyperactivity Disorder. Journal of Abnormal Child Psychology, 32(3), 285-293. doi: 10.1023/B:JACP.0000026142.11217.f2.

Scruggs, T. E. & Mastropieri, M. A. (1994). The utility of the PND statistic: A reply to Allison and Gorman, Behaviour Research and Therapy, 32(8), 879-883. Doi: 10.1016/0005-7967(94)90169-4.

Scruggs, T. E., Mastropieri, M. A., & Castro, G. (1987). The quantitative synthesis of single subject research: Methodology and validation. Remedial and Special Education, 8, 24–33. doi: 10.1177/074193258700800206.

Shapiro, E. S. (2008). Best practices in setting progress monitoring goals for academic skill improvement. In A. Thomas and J. Grimes (Eds.), Best practices in school psychology (Vol. 2, pp. 141-157). Bethesda, MD: National Association of School Psychologists.

Sharable Content Reference Object Model (SCORM®) [Computer software]. Advanced Distributed Learning.

Shinn, M. (2002). Best practices in using curriculum-based measurement in a problem-solving model. In A. Thomas & J. Grimes (Eds.), Best practices in school psychology (Vol. 4, pp. 671–697). Silver Spring, MD: National Association of School Psychologists.

Shinn, M. R., Gleason, M. M., & Tindal, G. (1989). Varying the difficulty of testing materials: Implications for curriculum-based measurement. The Journal of Special Education, 23, 223-233. doi: 10.1177/002246698902300208.

Sims, D. M., Purpura, D. J., & Lonigan, C. J. (2016). The relation between inattentive and hyperactive/impulsive behaviors and early mathematics skills. Journal of Attention Disorders, 20(8), 704-714. doi: 10.1177/1087054712464390.

Skinner, C. H., Belfiore, P. J., Mace, H. W., Williams-Wilson, S., & Johns, G. A. (1997) Altering response topography to increase response efficiency and learning rates. School Psychology Quarterly, 12(1), 54-64. doi: 10.1037/h0088947.

Skounti, M., Giannoukas, S., Dimitriou, E., Nikolopoulou, S., Linardakis, E. & Philalithis, A. (2010). Prevalence of attention deficit hyperactivity disorder in schoolchildren in Athens, Greece. Association of ADHD subtypes with social and academic impairment. ADHD Attention Deficit and Hyperactivity Disorders, 2(3), 127-132. doi: 10.1007/s12402-010-0029-8.

Smith, C. R., Marchand – Martella, N. E. & Martella, R. C. (2011). Assessing the effects of the "Rocket Math" program with a primary elementary school student at risk for school failure: A case study. Education and Treatment of Children, 34(2), 247 – 258. https://www.jstor.org/stable/42900585.

Sokal, R. R., & Rohlf, J. F. (1995). Biometry. San Francisco, CA: W.H. Freeman.

Solomonidou, C., Garagouni-Areou, F. & Zafiropoulou, M. (2004). Information and Communication Technologies (ICT) and Pupils with Attention Deficit Hyperactivity Disorder (ADHD) Symptoms: Do the Software and the Instruction Method Affect Their Behavior? Journal of Educational Multimedia and Hypermedia, 13(2), 109-128. Retrieved May 7, 2019 from https://www.learntechlib.org/primary/p/12868/.

Sood, A-B. & Sood, A., R. (2016). Attention Deficit Hyperactivity Disorder and DSM 5: What is new? In Malhotra, S. & Santosh, P. (eds.) Child and Adolescent Psychiatry, (pp. 33 – 50). India: Springer. doi: 10.1007/978-81-322-3619-1.

Sousa, D. A. (2016). How the special needs, brain learns. Corwin Press.

Sousa, D. A. & Tomlinson, C. A. (2011). Differentiation and the brain. How Neuroscience supports the learner-friendly classroom. Bloomington, IN: Solution Tree Press.

Vergou, N. (2018). Industry…of diagnoses of "learning disabled" children. Retrieved from http://www.efsyn.gr/arthra/viomihania-diagnoseon-paidion-me-mathisiakes-dyskolies [In Greek].

Wåhlstedt, C., Thorell, L.B. & Bohlin, G. (2009). Heterogeneity in ADHD: Neuropsychological pathways, comorbidity and symptom domains, Journal of Abnormal Child Psychology, 37(4), 551-564. doi: 10.1007/s10802-008-9286-9.

Wolraich, M. L., Wibbelsman, C. J., Brown T. E., et al. (2005). Attention deficit / hyperactivity disorder among adolescents: a review of the diagnosis, treatment, and clinical implications. Pediatrics, 115, 1734–1746. doi: 10.1542/peds.2004-1959.

Zentall, S. S., & Ferkis, M. A. (1993). Mathematical problem solving for youth with ADHD, with and without learning disabilities. Learning Disabilities Quarterly, 16(1), 6-18. doi: 10.2307/1511156.

Zentall, S. S., Smith, Y. N., Lee, Y. B., & Wieczorek, C. (1994). Mathematical outcomes of attention-deficit hyperactivity disorder. Journal of Learning Disabilities, 27, 510–519. doi: 10.1177/002221949402700806.

Zentall, S. S., Tom-Wright, K., & Lee, J. (2013). Psychostimulant and sensory stimulation interventions that target the reading and math deficits of students with ADHD. Journal of Attention Disorders, 17(4), 308-329. doi: 10.1177/1087054711430332.

Zentall, S. S. (2007). Math performance of students with ADHD: Cognitive and behavioral contributors and interventions. In D.B. Berch & M.M.M. Mazzocco (Eds.) Why is math so hard for some children? The nature and origins of mathematical learning and disabilities (pp. 219-243). Baltimore, MD: Paul H. Brokes Pub Co.

Zournatzis, E., Kakouros, E., Karamba, O., Papaeliou, X., & Badikian, M. (2001). The performance of children with ADHD on the basic academic sections. In 1st

Panhellenic Conference on Educational Psychology, Athens, GR. [Online]. Available: http://www.arsi.gr/presentations_in_conferences.html.