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COMPUTER ASSISTED INSTRUCTION OF STUDENTS WITH ADHD AND ACADEMIC PERFORMANCE: A BRIEF REVIEW OF STUDIES CONDUCTED BETWEEN 1993 AND 2016, AND COMMENTS

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Abstract:
Computer Assisted Instruction (CAI) is an instructional context that uses a computer as the mean for teaching pupils in individualized settings. CAI has been proposed as a compensatory instructional strategy among others for pupils with attentional, impulsivity and hyperactivity disorder (ADHD). This brief literature review synthesizes the outcomes of CAI to improve academic performance in various school disciplines for children with ADHD. First, it addresses research that studies the impact on academic disciplines performance of elementary school individuals with ADHD. Second, it considers methodological and pedagogical aspects of the studies reviewed. Finally, comments and recommendations, either in instructional and research context are made. Most of the studies reviewed suggested that CAI is an effective strategy in order to improve academic skills of pupils with ADHD. Moreover, an improvement in on-task and a decrease on error and off-task behaviors emerged as a byproduct of CAI intervention in some of those studies.

Keywords: ADHD, Computer assisted instruction, academic performance, brief review, comments

1. Introduction

Since the second half of the last century, Attention Deficit Hyperactivity Disorder (ADHD) became a worldwide phenomenon and since then, a real hot point of

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discussion (Graham, 2006). ADHD is a neurodevelopmental disorder, and its diagnosis applies to children that exhibit a rather developmental inappropriate profile regarding attention, hyperactivity, and impulsivity (APA, 2013).

DSM V refers to some essential features that form the diagnostic criteria of ADHD (APA, 2013). First, a "*… persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development*" have to be present (p. 59). Second, "*several inattentive or hyperactive-impulsive symptoms must have been present prior to 12 years of age*". Third, an impairment caused by the above symptoms must also be present in two different child's placements. Forth, "*there is clear evidence that the symptoms interfere with, or reduce the quality of, social, academic, or occupational functioning and finally, these symptoms do not occur and are not explained by another psychotic or mental disorder*" (p. 60).

This profile mediates negatively everyday functioning at school, at home and other settings. As a result, students with ADHD encounter problems with sustaining attention to specific stimuli and especially academic tasks or activities; they do not follow directions and always being distracted by extraneous stimuli. This maladaptive and developmental inappropriate profile of students with ADHD affects their school life and has a rather negative impact on their overall academic achievement. Students' academic deficient achievement affects various disciplines, like reading, writing, mathematics, science (Barkley, 2006; Brand, Dunn, & Greb, 2002; DuPaul & Vople, 2009). Over the last 30 years, some teaching strategies have been suggested and supported to be efficient. One of them, targeting students' with ADHD, academic performance is Computer Assisted Instruction (CAI).

Computers' use as a portion of the instructional procedure was presented by Skinner (1958), but it was not before 1970's that microcomputers' use in education became the focus of studies (Benjamin, 1988). This research period was followed by the "internet" one when online educational treatment was evaluated, in the early millennium (Aslan & Reigeluth, 2011).

Research on CAI use has been proposed as a quite promising intervention through almost thirty years (1967 to 1991). Reviews and meta-analyses of studies in this period suggested that CAI was a valid instructional strategy, especially for nondisabled[ii] students (Kulik & Kulik, 1991; Kulik, Kulik, & Bangert-Drowns, 1985). As computers' use in daily classroom instruction was expanding, many studies in CAI were conducted in the last twenty years, along with several reviews and meta-analyses (Bayraktar, 2001; Blok, Oostdam, Otter, & Overmacht, 2002; Fuchs, Fuchs, Hamlet,

[ii] The use of "nondisabled" word follows the guidelines of APA (2010) and refers to students without disabilities.

Powell, Capizzi, & Seethaler, 2006; Liao, 2007; Liu, Moore, Graham, & Lee, 2002; Slavin & Lake, 2008; Soe, Koki, & Chang, 2000). Most of those reviews and meta-analyses presented findings in phonological awareness, beginning reading, math and science performance improvement of nondisabled students. Research on CAI has also expanded on interventions for students with special educational needs.

Special education took advantage of data gained by studies in the effectiveness of CAI. Thus, Schmidt, Weinstein, Niemiec, and Walberg (1985-1986) reviewed studies on CAI for students either at risk or diagnosed with disabilities. They found that 23 out of the 26 studies supported CAI's effectiveness. Several studies, mostly single subject ones, studied CAI effectiveness on teaching students with autism, learning and other high incidence disabilities (Hall, Hughes, & Filbert, 2000; Pennington, 2010; Seo & Bryant, 2009; Stetter & Hughes, 2010).

In the 1980s a research interest in CAI's impact on academic performance of students with ADHD emerged. CAI's special features like visual and auditory stimulation and immediate feedback availability, along with step by step and in the students' pace presentation of tasks, suggested this strategy to be an opportunity for success in several academic fields (DuPaul & Stoner, 2003). As researchers supported, CAI could provide instructive and consistently efficient compensatory actions, in a pedagogical context of teaching strategies to overcome academic difficulties through direct instruction and scaffolding. Although repetitive tasks are associated with boredom and impulsivity of students with ADHD, computers could support rehearsals and repetitions for practice and fluency, in an active and motivated manner (Rieth & Semmel, 1991).

CAI effectiveness as an academic intervention for students with ADHD was examined by several studies between 1993 and 2016, and reviews and meta-analyses have been conducted. Alper and Raharinirina (2006) reviewed sixty studies focused on assistive technology for individuals with disabilities, including students with ADHD. Most of those studies examined CAI effectiveness in students' treatment. Although they suggested that computers and other assistive technology features could improve skills and performance of disabled children, they posed concerns about professionals' adequate training and usage of CAI. Kroesbergen and Van Luit (2003) presented a meta-analysis of fifty-eight studies of mathematics interventions for elementary students with special needs. Among those interventions was CAI and some of the participants of the studies were students with ADHD, supporting computers' use impact on achievement.

Respectively, DuPaul, Eckert, and Vilardo (2012) examined school-based interventions effectiveness, some of them referring to CAI, for students with ADHD.

They suggested that contingency management, academic intervention, and cognitive-behavioral intervention strategies were associated with positive effects on academic and behavioral gains. Fitzgerald, Koury, and Mitchen (2008) reviewed studies on Computer-mediated instruction impact on the learning of students with mild and moderate disabilities (ADHD among them) in curriculum content areas of reading, writing, and mathematics. Although they found computer use in daily instruction to be supportive to learning, they posed a lot of concerns about methods, samples and confounding variables' presence. Finally, Xu, Reid, and Steckelberg (2002) reviewed studies on technology applications, with computer-based instruction among them, in diverse areas of achievement (like academic, behavior and others) of students with ADHD. They concluded that there were little well-controlled experimental studies on the effectiveness of technology applications for students with ADHD.

The above reviews and meta-analyses offered data that need clarifications. Although most of them supported the value of CAI as a valid intervention for improving the performance of students with ADHD, no one was focused on CAI, students with ADHD and their academic achievement, at the same time. Some of them reviewed outdated studies, being out of the present technological literate context of instruction.

The purpose of the current review was to analyze studies regarding Computer-Assisted Instruction's impact on academic performance of elementary school-aged children with ADHD on reading, writing, mathematics and other academic disciplines briefly. Interventions concerning CAI, especially for students with ADHD, form a rather heterogeneous context. Nonetheless, a review could benefit instructional practice not only by positive outcome identification but also by deepening our understanding of those students and encountering their instruction in a differentiated and efficient way. Another aim of this review was also to comment and make recommendations for using CAI in compensating students' difficulties and providing their integration in typical classroom settings.

CAI was considered as a tool for instructional delivery, targeting students' with ADHD academic performance improvement, regarding practice and fluency or new academic skill establishment. Also, it's a brief review of studies concerning CAI implementation depending on and presented by the academic discipline context, not in chronological order. Moreover, it addresses concerns about the studies' methodology designs and hardware or software used, along with the presentation of pedagogical comments about instructional practice and research recommendations.

2. Method

2.1 Literature search procedure

Reviewed studies in this paper gathered after a keyword search in ERIC, Comprehensive Dissertation Abstracts and Base, EBSCO and Social Citation Index bases. The terms of search included "*attention deficit hyperactivity disorder, ADHD, attention deficit disorder, ADD, computer-assisted instruction, computer-based instruction, computer-mediated instruction, academic, reading, writing, mathematics, science, earth sciences, and arts."* The search resulted in a body of 53 studies, which were papers in journals, masters' theses and dissertations.

2.2 Criteria for study inclusion

To be included in this review, studies had to meet some of the criteria reported by DuPaul and Eckert (1997) in their meta-analysis:

1. Some or all participants had to be diagnosed as having ADD or ADHD. They could be diagnosed as having a comorbid disorder as well. When participants were medicated, it was stated.
2. Students had to be 6 to 14 years of age
3. The setting of the study was also described.
4. The study had to examine CAI as an academic intervention in curriculum content areas of reading, writing, mathematics, science, and arts.
5. Educational interventions could establish either fluency or a new skill.
6. Effect sizes would be presented only for studies that report them.

After applying the above criteria, only 22 studies remained to be reviewed, and descriptive information about them is presented in table 1. New skill development instruction was the aim of eight studies (36% of all studies), while the rest fourteen were targeted in practice and fluency improvement. Moreover, five studies (23%) examined CAI effectiveness versus traditional teacher-directed instruction. The majority of studies reviewed (13, 59% of all), examined specific software, while three of all studies (14%) considered particular hardware use effectiveness in the context of CAI.

2.3 Reading and writing

Reading and writing skills are located in the core of most countries' curriculums. Their educational value is considered to be significant and of great importance in students' academic performance, with or without special educational needs. Literacy skills have a global and recognized worth in developing overall academic skills of all students. Primarily for students with ADHD, reading and writing have been the focus of various

studies, as they frequently experience difficulties. Those difficulties were constantly related to ADHD symptoms likewise inattention and impulsivity (DuPaul & Langberg, 2014).

Academic skills of reading and writing have also been the focus of studies examining CAI's effectiveness in compensating students' with ADHD difficulties. Kingham and Blackmore (2003) studied the impact of a software program (Phonics Alive 2!) on phonological awareness and reading skills of three 2nd graders with ADHD and reading problems. Computerized sound blending and reading of either pseudo– or real words, were modules of the software. Although computer-based instruction increased phonological awareness and accuracy of word recognition, the speed of word recognition was gradually increased, but not at a rapid rate. Researchers suggested that the reason for fluency improvement failure was the limited time length of CAI intervention. Moreover, they concluded that CAI could benefit students' blending when preceded by an overview by the teacher.

In the same line of research, Bostian (2011) studied the effectiveness of "Earobics," an educational software for literacy development, on oral reading fluency of three 2nd graders with ADHD. A multiple baseline design across participants was utilized to examine the intervention effectiveness in a typical classroom setting. The software focuses on phonological encoding, converting sensory input about the sound structure into a representational form that can be stored in memory and phonological awareness. Bostian suggested that "Earobics" improved oral reading fluency and her findings were in total agreement with Walcott, Marett, and Hessel's (2014) and McDuffy's (2009) studies, examining "Earobics" effectiveness but on nondisabled students only.

In a multiple-probe design study (Regan, Bekeley, Hughes, & Kirby, 2014), four 6th grade disabled readers, one with ADHD among them, were instructed via a computer software (Lexia SOS) in a general education classroom and a resource room. The specific software incorporated activities including phonological awareness and manipulation of phonological units. The student with ADHD showed an upward trend in his performance and maintained intervention gains for a long time, although he exhibited a slightly lower reading fluency after CAI intervention. Regan and her colleagues suggested that CAI could play an important role in differentiating instruction in reading disabled students' mastering reading skills. As CAI was used as a supplement to student's regular core instruction, it was proposed that teachers have to plan and apply direct instruction principles prior to computer's use.

Earlier, Clarfield and Stoner (2005) had examined the effect of "Headsprout Reading Basics" software on beginning reading, using a multiple baseline design across

subjects. This software was designed to promote phonological awareness and oral reading fluency. Three students with ADHD, 6 to 7 years of age were at first taught by a teacher, traditionally, working on phonics, reading in groups or silently, and writing assignments. In the experimental condition, during a non-academic setting at afternoon, they were exposed to direct instruction by "Headsprout" software, completing an episode, each session. CAI effectiveness was supported as oral reading fluency increased, compared teacher-directed instruction. Moreover, off-task behavior decreased for all 3 participants relative to the small group and independent reading work. Although the effect size of the intervention was not presented, DuPaul, Eckert, and Vilardo (2012) calculated it (d = 7.93 CI 5.08 to 10.11) in their meta-analysis. As d was greater than 0.8 and zero was not included in confidence intervals (CI) value, they suggested that there was a significant effect size of the intervention over performance.

McClanahan, Williams, Kennedy, and Tate (2012) conducted a study examining the effectiveness of applications running in an iPad®, consisted of reading e-books, electronic flashcards, attending PowerPoint presentations and vocabulary builders' use. They assessed reading performance along with metacognition, before and after CAI intervention of a 5th-grade boy with ADHD. They found that the student gained almost a year's growth in his reading performance, within a six week period of iPad® intervention. They acknowledged the effectiveness of CAI per se, but they also underlined the impact of the specific device and its novel features.

In another study, Cullen, Kessey, Alber-Morgan, and Wheaton (2013) examined the effects of a computer program (Kurzweil 3000) on reading and writing acquisition of four African-American 4th graders with mild disabilities, one of them with ADHD. Those students had to type target sight words, highlight spoken words on a computer screen, read and say sight words into a microphone and complete a cloze passage. A multiple baseline design across word-sets demonstrated that CAI was related to the increase of sight word recognition of students, especially for the one with ADHD. Moreover, performance gains maintained four weeks after the intervention. Although findings were so positive, there was a concern about the extent that CAI could be widely applicable, as the Kurzweil software is quite expensive.

Conversely, three disabled students, 9-10 years of age (two of them with ADHD) were taught using CAI in Doughty, Bouck, Bassette, Szwed, and Flanagan's study (2013). One of the students was diagnosed with ADHD and medicated. The effects of a pentop computer's use accompanied by spelling software, in spelling performance of students were examined in a multiple baseline, single subject research design. FLYPen™ system, the pentop computer that was used, is a pen providing auditory prompts that students can use either during initiation of a new skill or practice of an old

one. Doughty and her colleagues used it along with various activities software, in a resource room setting, after teacher-directed traditional spelling instruction. Although academic engagement was increased using CAI, results indicated little or no improvement of spelling accuracy over conventional instruction.

In the same line with Doughty and colleagues' (2013) findings, Reid (2000) in her study suggested that overall spelling performance was not affected by CAI implementation. Six students with ADHD (10-11 years old), were exposed to teacher-directed and computer-assisted spelling instruction for three weeks each. Multiple baseline and intervention design ABAB was used. CAI was not found to be more efficient compared to traditional instruction in spelling, contrary to engagement time that was significantly increased when a computer used in the intervention.

Nevertheless, not only studies on basic reading and spelling skills for young students have been conducted. In a recent study, Andreou, Riga, and Papayiannis (2016) examined Information and Communication Technologies effect in improving the writing performance of students with ADHD. Sixty-six participants diagnosed with ADHD, all 13 to 14 years of age, were separated into two groups. One group (*N*=32) was instructed by using various computer-based tools, such as videos on a PC and semi-completed CMAP concept maps, while the other one (*N*=34) taught by a "pencil and paper" traditional intervention. All participants were instructed simultaneously the same educational material, in general education classrooms. Students' writing performance in two groups was assessed by a rubric criterion-referenced task of writing an essay. Andreou and her colleagues' findings indicated that the CAI condition group outperformed students in the traditional instruction group. Researchers remarked that CAI along with the use of teacher-guided discovery method contributed considerably to students' writing skills improvement.

In sum, CAI proved to be a rather useful instructional strategy for students with ADHD in literacy skills improvement. There have been found overall reading performance gains along with enhancements in prerequisite skills, like phonological awareness and decoding ones. The same pattern of findings was presented for writing skills as well. Overall performance in writing along with other skills, like spelling and composition were significantly improved for students with ADHD.

Although word recognition accuracy was also improved, reading speed had a slight decrease. Respectively, though writing performance was increased, a slight decrease in writing rate was found. Possible explanations for this pattern of data could be either the limited time of CAI intervention or the parallel improvement of students' with ADHD metacognition (McClanahan, Williams, Kennedy, & Tate, 2012). As they improved their reading and writing skills, they became more strategic readers and

writers. Using the majority of their cognitive resources to read or/and write more accurately, they fall behind with reading or writing speed (Schoonen et al. 2003).

2.4 Mathematics

Another skill, central to the academic curriculum, is mathematics. The centrality of mathematics is due to the high importance of this group of skills in students' development. As Zentall (2006) suggested, students with ADHD present a rather deficient mathematical performance profile. This underachievement profile has been related to attention deficits and is displayed in almost all mathematical subskills like numerical enhancement, math concept development, computational and problem-solving skills.

Mathematical skills were studied more and deeper than any other academic subject in the context of CAI. Researchers focus on pre-, basic and more complex mathematical skills. Slate, Meyer, Burns, and Montgomery (1998) for instance, investigated the influence of a computerized cognitive-training system (Captain's Log), on the behavior and performance of mathematical vocabulary of four 7 to 11 years old students with ADHD and comorbid emotional disorders. They were all medicated for an extended period of time. A behavioral point system and monitoring of progress on computer tasks were used, during the sixty-four sessions, administered over a 16-week period. Three out of four participants in the study showed improvement in mathematics receptive vocabulary, while two of them were found to improve daily behaviors. Also, as Slate, Meyer, Burns, and Montgomery suggested, the most successful students in the CAI condition, demonstrated the highest levels of generalization of mathematics vocabulary skills, as "*…CAI appears to provide a worthwhile complementary treatment to traditional interventions*" (p. 435).

Performance on subtraction was the focus of Nordness, Haverkost, and Volberding's (2011) study. The purpose of their single-subject, multiple-baseline design study, was to examine the use of a mathematical flashcard application on an Apple iPad®, to improve subtraction skills of three 2nd graders, one of whom, diagnosed with ADHD. All students were attending the resource room of their regular schools. In the baseline, their performance in subtraction was assessed by a normative test battery (Nebraska Abilities Math Test), and afterward, they used the flashcard software application. Although a visual inspection of his performance revealed a consistently upward trend, data suggested that the CAI condition of treatment had a moderate effect on students' with ADHD performance (*d =.57*). Researchers suggested that as students' with ADHD weekly average practice performance was consistently above 90 percent,

actually, there was no space for substantial improvement, as he was doing well before the intervention.

Working in a new methodological context (conducted in school, participants were senior age elementary education students, the study of research integrity), Ota and DuPaul (2002) examined the effectiveness of software in mathematics performance of addition and subtraction (with and without regrouping) relative to a written seatwork condition. "Math Blaster," commercial math software, offering 50.000 different problems in a game format was used, along with online help and math tips. Feedback on CAI condition was immediate, frequent and individualized. The performance was measured not only by accurate responses, but for fluency too, by correct digits per minute paradigm (Skinner, Belfiore, Mace, Williams-Wilson, & Johns, 1997). Three 4th, 5th and 6th grade students with ADHD took part in the study, which took place in the special education setting of their general education school. Ota and DuPaul (2002) supported that CAI strategy improved mathematical performance, such as computational skills, compared to independent seatwork condition, but not significantly. According to researchers, the moderate improvement was the result of the limited time of intervention and the absence of control over unspecified changes during baseline (written seatwork). On the contrary, significantly higher performance in on-task behavior was found. However, DuPaul, Eckert, and Vilardo (2012) in their meta-analysis noted that Ota and DuPaul's study (2002) presented effect size (1.59) with confidence intervals from 0.39 to 2.61. As effect size was greater than 0.80 and zero was not included in the confidence interval, DuPaul, Eckert, and Vilardo (2012, p. 401) suggested that there was a significant effect size of CAI implementation over performance, presence in Ota and DuPaul's study.

Mautone, DuPaul, and Jitendra (2005) also conducted a study of CAI impact, in math performance and behavior in school classroom everyday instruction compared to traditional teaching math procedures, using "Math Blaster" software. Math instruction procedures, including direct instruction, personal study, and teamwork study consisted the traditional intervention condition. Three 2nd and 3rd graders with ADHD, not medicated, took part in the study on a single case design with visual graphics analysis. Significant improvement in math performance of addition and subtraction was found along with the increase in the levels of on-task behavior for all. The effect sizes of CAI in this study were twice the size of previous studies with the same research goals (Kulik & Kulik 1991), exceeded in all case 1.0. DuPaul, Eckert, and Vilardo (2012) calculated effect size of this study (d = 4.11, *CI* 1.90 to 5.69). Finally, Mautone, DuPaul, and Jitendra (2005) found that CAI has a high acceptance as an instructional strategy among students and teachers.

Another single-case pre-test, post-test nonexperimental study on CAI impact to ADHD students' mathematical performance was conducted by Smith, Marchand-Martella, and Martella (2011). The study aimed to examine the effectiveness of math fluency software called "Rocket Math" in the mathematics performance of a first-grade boy, diagnosed with ADHD. The student was working with the addition portion of "Rocket Math" software three days a week, for 15 minutes per day. Mathematical fluency was computed by correct problems solved per minute. Data of this study lead to the conclusion that CAI had a positive effect on student's with ADHD mathematical performance as there was an increasing rate of correctly completed mathematical problems per minute. The comparison of the student's performance during CAI and the pre- and post- test revealed differences, while error increase was not found.

The effectiveness of CAI on mathematical operations of addition and subtraction performance of students diagnosed with ADHD and their typical peers, in the context of an online Learning Management System (LMS) was studied by Botsas (2015). CAI condition consisted of electronic lessons, designed by the researcher in Articulate Storyline2®. Mathematical operation performance of students was assessed right before, just after and after three months' time with "paper and pencil" and CAI conditions, to determine maintenance of intervention's effects. Six students diagnosed as having ADHD attending 1st to 3rd grade of elementary school and not medicated took part in the study. They were facing minor to significant difficulties in mathematical operations of addition and subtraction. A group of twelve nondisabled students of the same age, with no mathematical challenges, was the control group.

CAI was found to be an effective instructional strategy on mathematical operations' performance either of students with ADHD or typical ones in an individualized "working at home" educational setting. Although all students had performance gains from CAI implementation, a differentiated pattern was revealed. Nondisabled and students with ADHD with minor difficulties, had more performance gains, which were maintained right after treatment and a follow up examination after three months. On the contrary, school-aged children with ADHD having significant difficulties, presented limited performance gains and faded out, when maintenance was examined in the follow-up condition. There was a significant effect size of CAI implementation on students' with ADHD performance (d = 2.33 CI 0.86 to 3.8). The perspective of school – home cooperation, based on CAI and LMS simultaneous efficient use was by this study (Botsas, 2015).

Moreover, multiplication was the focus of Koscinski and Gast's (1993) single subject multiple probe design study. They investigated the effectiveness of computer application, developed by them, incorporating the constant time delay instructional

procedure, to teach multiplication facts to six Learning Disabled students (9 to 10 years of age). Three of the participants were diagnosed as having ADHD and were medicated. Students were taught individually in a self-contained special education classroom. Fifteen unknown facts were presented via an auto-instructional computer program with a constant 5-sec time delay procedure. The results of the study indicated that CAI was effective in teaching multiplication facts to students with ADHD. Additionally, those students had differentiated gains based on their initial difficulties. As Koscinski and Gast (1993) proposed CAI software design, like time delay, is a crucial issue to improve academic and especially math performance of students with ADHD.

In her study, Tattrie (2003) compared the efficacy of CAI versus a context of small group teacher instruction for mathematics fraction modules (multiples and common denominators, improper fractions and mixed numbers, adding and subtracting fractions and multiplying fractions). Ten 6th to 8th graders with ADHD were assigned to two classes receiving alternatively either computer-assisted instruction (PLATO's Math Fundamentals: Fractions) with a teacher's presence or only teacher-directed instruction on four mathematics fractions. Pre- and post- assessment was conducted to examine performance gains and maintenance.

Contrary to the most studies reported in this review, no significant effectiveness differences were found between two instructional contexts, namely the CAI with teacher presence and the traditional teacher instruction. Tattrie reported no differences regardless of the material difficulty, prior knowledge or participants' skill level. Contradictory findings could be the result of the different modes of pre- and post-assessments versus CAI context. "Paper and pencil" conditions differ in a lot of their properties from the computer use context. Additionally, the researcher could not ensure that teachers in small group "paper and pencil" condition did not give more supportive information and help students more than computers. So, two intervention programs could not be comparable regarding integrity.

Bouhouna (2011) in her study examined the effectiveness of CAI in mathematical reasoning tasks on problem-solving of students with ADHD against a "paper and pencil" condition. One hundred and two 4th, 5th and 6th graders took part in the study assigned into two paired groups regarding age: a) the experimental group which consisted of 51 children with ADHD and b) the control group which included of 51 typically developing children.

Traditional teacher-directed instruction, not CAI condition, was related to higher performance in mathematical reasoning, problem-solving tasks regardless of ADHD existence. As Bouhouna suggested, problems' presentation on a computer screen was not more efficient than the "paper and pencil" one. The low-level CAI condition was

probably the reason of those findings, as extended literature in this field clarified that software in computer-assisted instruction has to be a rich game format software, not drill and practice or simple presentation one (Ford, Poe, & Cox 1993).

Additionally, some studies examine CAI and mathematical achievement of students with ADHD, along with other variables. Mathematics performance of school-aged children with ADHD was rather a background variable in the computerized choice to be the foreground one. Thus, Bennett, Zentall, French, and Giorgetti-Borucki (2006) conducted a study where CAI was used to improve the mathematics performance of students with ADHD, via a computerized choice of visual or auditory feedback. Nine ADHD diagnosed students and seventeen typical ones from 3rd to 5th grades took part in the study. Within and between group factors analyses were conducted. The research design also included two levels of group conditions, one for choice and one for problem-modality order. Participants were randomly assigned to choice and no-choice groups.

Students with ADHD performed less accurately than their typical classmates when problems were visual, but unexpectedly their accuracy in auditory problems was increased and reached the levels of their nondisabled peers' performance. As the speed of problem-solving, children with ADHD were found to react with lower speed than typical ones either in auditory or visual problems. Although these findings differentiate students with ADHD from their typical peers, significant differences were not found.

Finally, Kang and Zentall (2011) examined the effect of CAI and combined increased intensity of graphical information on students' with ADHD geometry performance. Eighteen (2nd to 4th grade) students, twelve of them diagnosed as having ADHD, took part in the study. They were firstly instructed in a "pencil and paper" traditional condition. Afterwards, there was an intervention in two CAI conditions (high and low intensity of graphics information). Kang and Zentall supported that students with ADHD performed better than their nondisabled classmates in difficult geometry problems. They outperformed nondisabled students, especially when there was a high visual intensity of graphical information in geometry problems presentation and elaboration.

CAI was found to be also useful in compensating mathematical difficulties of students with ADHD. The studies reviewed above suggest that CAI's use improved students' performance in mathematical subskills like establishing a receptive mathematical vocabulary, numeracy enhancement, along with computational skills and problem-solving. Although studies' findings lack generality as they had small samples, their data support CAI's instructional value strongly.

Contrary to reading and writing skills, CAI's use improved not only accuracy but the fluency of mathematical performance as well. A plausible explanation could be the one that Fitzgerald, Fick, and Milich (1986) suggested, that it was the complexity and difficulty of reading and writing tasks the reason of response speed decrease. While fluency, the speed of accurate performance, is related to higher metacognitive processes and complexity of monitoring and control of the flow of cognitive processes those differences found, could be attributed to metacognitive processes differences. When effortful control, the active fix-up process leading to accuracy, is enabled, a decrease or even lack of fluency will emerge (Kolić-Vehovec, 2002). As Touroutoglou and Efklides (2010) suggested, a lack (or reduction) of fluency arises when *"… complex tasks in which many, attention demanding, acts have to be executed*" (p. 174). That is, accuracy and fluency could be antagonistic to each other until automatization of a skill occurs.

Another significant issue that emerged from studies' on mathematics was software's characteristics and features. Raggi and Chronis (2006) proposed that material presented in a CAI context has to be in multiple modalities and in a students' self-paced mode. Additionally, DuPaul and Stoner (2003) supported that CAI was more effective when the software used was in game format, with colors and not excessive animations. Thus, for studies that did not support CAI's effectiveness towards traditional instruction, "by default" simple presentation of material could be the reason. A presentation similar to the everyday classroom instruction with no attention-catching and interest maintenance features could lead students with ADHD to boredom, lack of interest and consequently to off-task behavior exhibition.

2.5 Other academic disciplines in elementary school instruction of student with ADHD

Although the typical school's curriculum in most of the western countries is based on two critical foundations, reading and writing, along with mathematics, there are also other academic disciplines that affect students' development. Skills referring to science learning, arts, earth science and religion, based on high order thinking are significant to the curriculum. Students with ADHD also exhibit various difficulties depending on deficient attentional skills and impulsivity (Gravois & Gickling, 2002).

Some studies examined CAI effectiveness in other subjects, like science. Shaw and Lewis (2005) investigated the impact of the use of stimulating animations about science on a laptop computer. Twenty students with ADHD who were medicated, but abstained from taking their medication at least 4 hours prior to testing or processing tasks and typical ones took part in the study. Also, students, with ADHD or typical were assigned to mixed capability groups. They have presented science tasks in either

CAI or traditional instruction contexts. Results indicated that CAI was a useful context of intervention in science tasks as students with ADHD produced more accurate responses even against nondisabled students when instructed by a computer on more traditionally presented "paper and pencil" condition.

Finally, Solomonidou, Garagouni-Areou, and Zafiropoulou (2004) conducted a study examining the impact of various educational software, in a CAI context, on behavior and academic performance of students with ADHD. Nine fifth and sixth – graders with ADHD and four age-matched students without ADHD took part in the study. All students were separated into two groups, one group of five students with ADHD that would receive CAI context treatment and another group of eight students (the four students with no ADHD included) that would work in a collaborating context. As the researchers mentioned above proposed, CAI was proved to be an effective instructional context that allows students with ADHD to self-act and interact in an academic environment that is structured, full of stimuli and interaction. They suggested that CAI environments have to be constructivist and of average difficulty to be effective. Furthermore, researchers supported that the best CAI instructional setting for students with ADHD is the individualized one as the collaborative setting caused students with ADHD to present disrupted behavior. However, they collected no quantitative data, presenting information qualitatively and exposed to severe criticism.

Computer Assisted Instruction was found to be an effective instructional strategy for bridging children's with ADHD difficulties in academic disciplines other to reading, writing, and mathematics. Science, earth sciences learning, arts and other subjects could be accessed by students with ADHD in a more efficient manner. CAI's features like stimulating animations and active interaction could bypass inattention difficulties or boredom of traditional instruction context (Rieth & Semmel, 1991). Additionally, a constructivist structure of CAI strategy, along with a differentiated context of individualized instruction has to be placed (Sousa & Tomlinson, 2011). As for the instructional level, that has to be of average difficulty, at least near student's functionality level, to encounter boredom, impulsivity or disruption (Regan, Berkeley, Hughes, & Kirby, 2014).

Table 1: Review of studies of CAI by academic discipline and year of publication

Reading and writing					
Citation	**Participants**	**Focus**	**Procedures**	**Assessment**	**Findings**
Reid, 2000	6 ADHD	Examine the effects of CAI in spelling versus teacher-directed instruction on ADHD students' performance New skill instruction	Multiple baseline (teacher instruction) and intervention (CAI) conditions	Percentage of words spelled correctly	Overall spelling achievement of children with ADHD did not appeared to be affected by CAI
Kingham & Blackmore, 2003	2LD + 1 ADHD 2nd graders	CAI instruction of phonological awareness and reading decoding with "Phonics Alive 2! The Sound Blender" New skill instruction	Baseline: Assessment with Tests Experimental1: CAI condition Experimental2: CAI plus teacher overview condition	Phonemic Awareness Test Word and pseudoword lists	Students showed improvement in phonological awareness and decoding accuracy but not in recognition speed. It is concluded that best results could be reached with CAI along when preceded with overview by the teacher
Clarfield & Stoner, 2005	3 ADHD	Headsprout effect on beginning reading instruction Practice and fluency	Observation Baseline: Typical classroom activities Experimental: CAI condition	DIBELS – Oral Reading Fluency (1996)	CAI resulted increase in oral reading fluency and decreases off-task behavior compared with teacher-directed instruction
Bostian, 2011	3 ADHD 2nd graders	The effect of the CAI program "Earobics" on literacy skill development for second grade students Practice and fluency	Baseline: Oral reading fluency assessment (DIBELS) Experimental: CAI with software "Earobics", focusing on phonological encoding	Assessment for oral reading fluency and observations.	"Earobics" use promoted students' oral reading fluency and duplicated Walcott, Marett and Hessel's (2014) and McDuffy's (2009) data
McClanahan, Williams, Kennedy & Tate (2012)	1 ADHD 5th grader	Reading, reading comprehension and metacognition about reading New skill instruction	CAI use in 5grades. Every session was divided in first half (typical instruction) and second half (CAI). Reading strategies' instruction with various software.	Assessment of word recognition and reading comprehension. Informal reading inventory and teacher's observations through 5 grades and sessions	Comparisons showed that the student had gained one year's growth in reading within a six weeks period. The student also gained in confidence and sense of being in control of his learning.

Citation	Participants	Focus	Procedures	Assessment	Findings
Cullen, Keesey, Alber-Morgan & Wheaton, 2013	3 LD + 1 ADHD 4th graders	The effects of a computer-assisted instruction program (Kurzweil 3000) on the acquisition of sight words for four African American New skill instruction	Baseline: sight words (Dolch) Experimental: Kindergarten interactive PC activities. Kurzweil 3000. Sight words learning, writing words, pick the right word from a list and place it in text	Sight words lists (Dolch) Software assessment	All four students mastered the target sight words within two to seven 20 to 25-minute sessions. Additionally, three students demonstrated maintenance of the sight words they acquired up to four weeks after the computer intervention was discontinued.
Doughty, Bouck, Bassette, Szwed & Flanagan, 2013	3 disabled students (2 ADHD) One medicated	Examine the effects of a pentop computer and accompanying spelling software on the spelling accuracy and academic engagement behavior in three elementary students with disabilities who were served in a resource room setting New skill instruction	Baseline: teacher-directed instruction in resource room with other three disabled students (six sessions) Experimental: CAI individualized intervention using FLYPen™ with software including geography activities, word mazes, word scratch walls etc. Maintenance	Words spelled correctly Graphophonemic awareness	While academic engagement performance increased considerably for students when using the FLYPen™, results indicated little to no improvement over traditional instruction in spelling accuracy.
Regan, Berkeley, Hughes & Kirby, 2013	4 mild disabled students 1 ADHD	Examination of CAI effects (Lexia Strategies for Older Students (SOS)™) on the word recognition skills of four, upper elementary students with mild disabilities Practice and fluency	Instructor training Baseline: read aloud (no CAI) Instruction: use of "LEXIA SOS" software Maintenance Generalization: probes after 5 and 10 days	Assessment in software RFBA (Read Naturally, 2008)	Findings revealed that some students were able to meet mastery of basic word reading skills with "Lexia SOS" alone, while others needed additional direct instruction. ADHD student reached mastery but after additional instruction

Citation	Participants	Focus	Procedures	Assessment	Findings
Andreou, Rigas & Papayiannis, 2016	66 ADHD (13-14 years old)	ICT effect in improving students' with ADHD writing performance Practice and fluency	Participants separated in two groups ICT-CAI (*N*=32) and "paper and pencil" group (*N*=34)	Assessment on the basis of their ability to write a descriptive essay. The assessment task relied on the performance criteria that were included in an analytic rubric. It is well known that analytic rubrics draw lines between as well as evaluate specific textual attributes, each with its own description and scoring scale	The findings indicate that the group of students who used ICTs performed better in the task of essay writing than the group who did not.
Mathematics					
Citation	**Participants**	**Focus**	**Procedures**	**Assessment**	**Findings**
Kosckinski & Gast, 1993	3 LD and 3 ADHD 9-10 years old ADHDs were medicated	Multiplication skills in CAI sessions New skill instruction	Baseline: screening for knowledge using flashcards Experimental: individualized auto-instruction in CAI sessions (multiplication software with probes)	Flashcards assessment Software assessment in errors, time and sessions of meeting the criterion	CAI was effective in teaching multiplication facts to students with learning disabilities and ADHD.
Slate, Meyer, Burns & Montgomery, 1998	4 ADHD (7 to 11 years old) All medicated	Investigation of the influence of a computerized cognitive-training system (Captain's Log) on the behaviors and performance capabilities of students with ADHD Practice and fluency	A behavioral point system and monitoring of progress on computer tasks was used, during sixty four sessions administered over a 16-week period.	WISC-III (1991) WRAT-3 (1984) PPVT-R (1981) Trail Making Test (1976) IVA (1994) CBCL & TRF (1986) Conners Parent and Teacher Rating Scale (1985) Electroencephalograms	Three out of four participants in the study showed improvement in mathematics receptive vocabulary, while two of them were found to improve daily behaviors.
Ota & DuPaul, 2002	3 ADHD 4^{th}, 5^{th} & 6^{th} graders All medicated (1 inattentive, 2 combined subtype)	Math performance improvement using CAI (game format software–Math Blaster (Davidson & Asssociates, 1999) as a supplement to teacher's instruction Practice and fluency	Baseline: observations under normal classroom conditions Experimental: Math software presentation sequentially	Math skill probes: Adding (with & without regrouping) and Subtracting without regrouping Curriculum based measurement Digits and problems correct per minute	All participants showed improvement in performance Similar findings to Ford et al, 1993 and expended their data. Problems in generalization. Modest improvement

Citation	Participants	Focus	Procedures	Assessment	Findings
Tattrie, 2003	10 ADHD 6th to 8th graders All medicated	Effectiveness of CAI (PLATO's Math Fundamentals: Fractions) + Teacher vs Teacher conditions in math fraction instruction New skill instruction	Baseline: Paper and pencil assessment Experimental: Teachers instructed math fractions in modules the two groups (CAI, Teacher)	"Paper and pencil" pre- and post-test	No significant differences between the effectiveness of the two instructional methods for teaching fraction modules, regardless of material difficulty, prior knowledge or participant skill level.
Mautone, DuPaul & Jitendra, 2005	3 ADHD 2nd & 3rd graders All medicated (1 inattentive, 2 combined subtype)	The effects of CAI (game format software–Math Blaster (Davidson & Asssociates, 1999) on the mathematics performance and classroom behavior Practice and fluency	Baseline: observations under normal classroom conditions Experimental: Math software presentation sequentially	Math skill probes: Adding (with & without regrouping) and Subtracting without regrouping Curriculum based measurement Digits correct per minute	All three participants increased correct digits per minute performance
Bennett, Zentall, French & Giorgetti-Borucki, 2006	9 ADHD & 17 non ADHD 3rd to 5th graders	Improvement of math tasks performance (addition problems) in a CAI condition offering students choice over feedback New skill instruction	Two CAI visual and auditory modality feedback presentation of math problems Choice no-choice conditions	Accuracy: number of correct answers in 60 problems per trial Speed: sum of elapsed time for each problem answered correctly in each trial	CAI condition was found to be more effective there were no strong signs of generalization against unconstructed condition. CAI or direct instruction will produce permanent discovery learning gains only if they are implemented for a long period of time
Bouhouna, 2011	104 4th, 5th and 6th graders (52 ADHD)	Examined the effectiveness of CAI in mathematical reasoning tasks on problem solving of students with ADHD against a "paper and pencil" condition. Practice and fluency	Baseline: Traditional teacher-directed instruction Experimental: CAI condition (Presentations)	Problem solving in two conditions (paper and pencil & CAI)	Traditional instruction, not CAI condition was related to higher performance in mathematical reasoning problem solving tasks regardless of ADHD existence.

Citation	Participants	Focus	Procedures	Assessment	Findings
Kang & Zentall, 2011	18 2nd to 4th grade 12 ADHD (4 inattentive 8 combined type)	CAI instruction with increased intensity of graphic information benefits ADHD students' geometry performance Practice and fluency	Baseline: paper and pencil instruction Experimental: CAI instruction in two conditions (High and Low Visual Intensity)	Performance measures pre and post intervention	ADHD students performed better than typical comparisons in advanced geometry problems especially in High Visual Intensity condition
Nordness, Haverkost & Volberding, 2011	2 LD and 1 ADHD 2nd graders	The effect of a mathematic flashcard application on a hand-held computing device Practice and fluency	Baseline: Assessment of subtraction skills Experimental: Sessions of CAI use (Math Magic)	Nebraska Abilities Math Test (N-ABLES) Software assessment	All of the students improved their subtraction scores by an average of 17% as measured by the district-created, curriculum-based assessment, especially ADHD one
Smith, Marchand-Martella & Martella, 2011	1 ADHD 1st grader	The effects of the "Rocket Math" program on the math fluency (addition) skills Practice and fluency	Baseline: Curriculum based assessment and individualized checkouts. Typical instruction Experimental: Instruction using software	Pre- and posttest curriculum-based measurement (CBM) and individualized fluency checkouts within the program	The participant increased his addition performance in the post test
Botsas, 2015	18 (1st to 3rd graders) 6 ADHD (2 inattentive, 2 hyperactive – impulsive, 2 combined subtype)	The effectiveness of CAI on mathematical operations of addition and subtraction performance of students with ADHD and their typical peers, in the context of an online Learning Management System (LMS) Practice and fluency	Baseline: Pencil and paper assessment Experimental: CAI condition in software developed by researcher	Paper and pencil, along with software assessment. Correct digits per minute Curriculum based Assessment	CAI was found to be an effective instructional strategy on mathematical operations' performance either of students with ADHD or typical ones in an individualized "working at home" educational setting. Although all students had gains from CAI implementation, a differentiated pattern of performance was revealed.

Other disciplines					
Citation	**Participants**	**Focus**	**Procedures**	**Assessment**	**Findings**
Shaw & Lewis, 2005	20 ADHD and 20 typical students from 7 to 10 years of age	This study investigated the impact of the use of a laptop computer, with and without stimulating animations and features incorporated into task presentation, on Key Stage 2 level science tasks for ADHD students. Practice and fluency	"Paper and pencil" condition with and without animation Computerized condition with and without animation	Wechsler Abbreviated Scales of Intelligence (WASI) (1999) British Ability Scales II Word Reading Card (1996).	ADHD students produced the greatest number of accurate responses on the more basic computerized tasks (presented as simple Microsoft Word documents) and exhibited significantly more on-task activity on animated computerized tasks. In summary, computerized presentation significantly improved the accuracy of responses and the on-task focus of participants with ADHD.
Solomonidou, Garagouni-Areou & Zafiropoulou, 2004	9 ADHD and 4 typical elementary school students	The effect of ICT (CAI) use on students' academic performance Practice and fluency	Individual and collaborative sessions in Art, History, Physics, Geography, Mathematics	Software assessments Teacher's observations	Students with ADHD had significant better behavior and performance. They prefer reading short texts, watching short videos and listening short narration items while working on the computer.

2.6 Synopsis and comments on CAI effectiveness and computer's use

DuPaul and Eckert (1998) proposed CAI as an effective intervention in increasing the on-task and work production behaviors of students with ADHD (p. 68). That is, when a computer is used in interventions targeting students' with ADHD achievement, attention, persistence, and motivation are increased. However, most of the studies reviewed above suggested that computer-mediated instruction might also be useful in improving the academic performance of children with ADHD.

Computer-Assisted Instruction offers a novel, attention-grabbing approaches when addressing critical context (graphics, words, sounds, etc.), vital to academic task management and increasing performance. (Xu, Reid, & Steckelberg, 2002). As studies reviewed suggested, CAI has a positive impact on students' with ADHD performance in some academic disciplines like reading, writing, mathematics, and science. More specifically its effect was found to be significant to various levels of basic skills like reading, for instance from in decoding (Regan, Berkeley, Hughes, & Kirby, 2014) and oral reading fluency ones (Walcott, Marett, & Hassel, 2014). Also, there was a significant effect in the mathematical subskills of mathematical vocabulary acquisition, numerical enhancement, mathematical operations and problem-solving.

Although moderate effect sizes (d = 0.30 to 0.47) have been noted in meta-analyses of studies referring to CAI effectiveness in nondisabled students' performance (Kulik & Kulik, 1991; Kulik, Kulik, & Bangert – Drowns, 1985), the effect sizes in studies where students with ADHD participating were larger. Effect sizes from d = 1.59 (Ota & DuPaul, 2002) to d = 4.11 (Mautone, DuPaul, & Jitendra, 2005) were found. A possible explanation could be the educational manipulation of CAI features (feedback, visual and auditory cues, animation, curricular adaptations, etc.) that could fit better with students with ADHD. Moreover, the actual academic subject of mathematics could be more suitable for CAI intervention for students with ADHD (Raggi & Chronis, 2006).

Apart from the CAI impact on academic performance, there were explicit findings of increasing attention, reducing impulsivity and as a result, increasing on-task behavior, persistence, and motivation (Bouhouna, 2011; Ota & DuPaul, 2002). Those instructional results could help students with ADHD improving their school performance and their social status in their classroom. The more positive feedback they take at school, the higher their motivation will be. Additionally, there have been findings of performance gains generalization of CAI intervention after a period of time (Botsas, 2015), nominating CAI as a valid and in the long run effective instructional strategy for students with ADHD.

CAI effectiveness varied over student's academic level. More efficient learners presented more academic gains and higher generalization levels than less able students

(Koscinski & Gast, 1993; Slate, Meyer, Burns, & Montgomery, 1998). This could be an indication of "Matthew effect" existence, but more and more thorough studies have to be conducted (Botsas, 2015). Consequently, the tasks used in CAI intervention have to be near at the performance level of a student with ADHD (Ford, Poe & Cox, 1993) contributing to differentiated instruction (Regan, Berkeley, Hughes, & Kirby, 2014).

Additionally, a comment has to be done in reference of subtypes of ADHD and their contribution to the studies' findings. It was documented that the beneficial effects of CAI were a function of not only previous difficulties but also of personal ADHD characteristics and their severity as well (Botsas, 2015; Clarfield & Stoner, 2005; Mautone, DuPaul, & Jitendra, 2005; Ota & DuPaul, 2002). Only a few of the reviewed studies addressed subtypes of ADHD in their sample and controlled over the experimental procedures and their results (Botsas, 2015; Clarfield & Stoner, 2005; Mautone, DuPaul, & Jitendra, 2005; Ota & DuPaul, 2002). Findings supported that performance improvement between participants with ADHD was also a function of the diagnosis of their subtype (combined presentation, predominantly inattentive and predominantly hyperactive-impulsive presentation) (APA, 2013).

Moreover, there was another concern about participants that were medicated (Doughty, Bouck, Bassette, Sawed, & Flanagan, 2013; Koscinski & Gast, 1993; Ota & DuPaul, 2002; Reid, 2000; Slate, Meyer, Burns, & Montgomery, 1998; Tattrie, 2008). It was difficult to differentiate the improvement of students' performance that was caused by CAI, medication or both. Thus, Ota and DuPaul (2002) suggested that a combination of interventions could be used to maximize performance gains of students with ADHD. Computer use in individualized instructional settings was found to be more effective than cooperative small group instruction or independent traditional work (Clarfield & Stoner, 2005). CAI could be a significant weapon in a teacher's arsenal of compensating difficulties of students, those with ADHD included, in the context of inclusion and differentiation of instruction (Sousa & Tomlinson, 2011). That is, taking into account students' potential, interest and learning style when planning instruction, CAI use could be an effective strategy to differentiate intervention and include students with ADHD.

However, some of them did not support or partially supported CAI's efficiency in students' with ADHD performance improvement. Possible explanations for lack of positive effects, like limited time or inappropriate intervention context, were proposed. ADHD symptoms have a significant impact on students' performance, so academic interventions have to be competitive and long-term. Teaching students' with ADHD is challenging either implementing it in a traditional way or in a CAI context. Thus, simple presentation-like interventions, with no attention-grabbing elements, limited

and not appropriate feedback, along with short-term application, could be the reason of mixed or negative data for CAI's efficiency.

Most of the studies reviewed proposed that some of the characteristics of computer-based instruction promoted performance per se. Raggi and Chronis (2006) suggested that such CAI characteristics and features could be a presentation of learning the task in multiple modalities, chunking them as well to be easily manageable. Additionally, CAI could serve as a helping variable for the student to self – paced and step by step elaboration of a task, as models of task completion, including concrete examples (Bender & Bender, 1996). Moreover, computer use in students' with ADHD instruction could limit distraction, non-essential features' processing. This finding could be proved an effective strategy for compensating students' with ADHD, academic performance (DuPaul & Weyandt, 2006, p. 168). Findings of those studies supported that CAI was more effective whenever instructional software was in a game-format, with colors and no excessive animations. Other features that could prove CAI an effective instructional strategy for school-aged children with ADHD are the presence of visual and auditory stimuli and immediate feedback availability (DuPaul & Stoner, 2003).

However, some concerns emerged from the body of CAI effectiveness literature. Almost all the studies reviewed, used a single case with multiple baseline and intervention research design. Furthermore, most of them had small sample sizes and examined CAI effectiveness over relatively short periods of time (DuPaul & Weyandt, 2006; Kingham & Blackmore, 2003; Nordness, Haverkost, & Volberding, 2011). The majority of those studies used a convenient sample procedure, as students diagnosed with ADHD present a wide repertoire of characteristics, across the three subtypes of the disorder (predominantly inattentive, hyperactive-impulsive and combined) (Barkley, 2006). None of the studies reviewed used a randomized sample, in order to increase validity.

Additional concerns could also emerge about the inclusion of participants in some studies. First, in a number of studies, students were not formally diagnosed with ADHD, but included in the sample after teachers' evaluations based on reliable instruments (Bostian, 2011; Bouhouna, 2011; Kang & Zentall, 2011; Solomonidou, Garagouni-Areou, & Zafiropoulou, 2004). Second, there is another concern about the comorbidity of ADHD with other disorders. Students with ADHD present a great variety of profiles themselves. Whenever a comorbid disorder is present, it is sound to be controlled for its impact in the way that student reacts to stimulation (Doughty, Bouck, Bassette, Szwed, & Flanagan, 2013; Kingham & Blackmore, 2003; Shaw & Lewis, 2005; Slate, Meyer, Burns, & Montgomery, 1998).

Concerning the validity of the generalization of findings, some of the studies lack follow up (generalization) data, limiting firm conclusions (Daly, Creed, Xanthopoulos, & Brown, 2007). Moreover, only some of the researchers used integrity of intervention measures or interobserver, to ensure that interventions' implementation was reliable. There are methodological manipulations in some of those studies referring to a "one size fits all" approach violating the major "law" of differentiated instruction due to student's learning readiness, learning style and interests (Sousa & Tomlinson, 2011). Furthermore, some of the studies mentioned above (especially older ones) took place in laboratories and clinics, not in students' with ADHD natural educational settings (school and home) (Botsas, 2015).

Computer-Assisted Instruction sometimes is an expensive intervention and concerns have emerged about its effectiveness versus cost ratio (Cullen, Kessey, Alber-Morgan, & Wheaton, 2013). Although some technologies supporting CAI are quite expensive, sometimes are the only alternative effective instructional strategy to be implemented in students' with ADHD treatment. Moreover, nowadays, the technology of computers is getting easier to use (Botsas, 2015) and cheaper to buy (Mautone, DuPaul, & Jitendra, 2005), making CAI a useful, essential and more accessible strategy. As CAI becomes more popular among teachers, instructional practices for students with ADHD will be enriched with new ideas and models, effective in their performance improvement.

Finally, not all CAI studies demonstrated clear dominance over other interventions like teacher traditional instruction (Fitzgerald, Fick & Milich, 1986; Tattrie, 2003). Despite methodological concerns about such studies, like sample or procedure manipulations or tasks' nature (Raggi & Chronis, 2006) they posed questions about CAI's impact on performance increase.

In recent years, special education, along with families and need for inclusion of students with ADHD, poses a lot of concerns about the quality of educational research in the field. Mixed findings of studies on CAI effectiveness, along with methodological concerns presented above, make high research quality a significant request. Evidence or research-based quality indicators have been set in order to guide teachers of students in special education and in instruction of students with ADHD (Gersten et al., 2005; Edybrun, 2013; Odom et al., 2005). Thus, quality indicators of describing participants, implementing the intervention and description of comparing conditions, of the outcome measures and data analyses are applied in order to consider an intervention as research-based. Although most of the studies reviewed in this paper presented data supporting CAI effectiveness, they were not meeting the conditions to be considered as evidence or research-based intervention, but as a promising one.

Conclusively, CAI has been proposed as a valid and efficient yet promising strategy for teaching students with academic difficulties, students with ADHD included. This strategy could change the teaching and teaching paradigm constraining students to become more independent and self-directed, mastering the educational material (Means, Penuel, & Padilla, 2001). This altered paradigm eventually changed special education's practice, as CAI was found to be a very effective instructional strategy for students with special educational needs (Ayres, Meching, & Sansosti, 2013). As Lewandowski, Wood and Miller (2016) stated "*in particular, a computerized educational world has made it easier to find information, present information, communicate, and respond. It has helped students with disabilities circumvent certain problems and adapt things in a way that might make their learning easier*" (p. 84).

Moreover, CAI's effectiveness and computers' use, in general, are connected to technology use per se. Nowadays, innovations in technology are presented in a vast speed mode, and new methods of interacting each other bring new sources of distractions, but tremendous potential as well (Ziegler, Mishra, & Gazzaley, 2015). Together with technology, especially computer innovations, goes the notion that children, even of elementary school age use computers in a way that is compatible with emerging new technology literacy. Moreover, those children in western societies seem to participate in a global technological culture.

Regarding this technological culture, students with ADHD have their share, and CAI context is a way to be included, even if there are some concerns about this. Those concerns could involve behaviors and risks about unattended occasions like the internet or social media use (Carrier, Black, Vasquez, Miller, & Rosen, 2015; Kowalski & Whittaker, 2015). But computer use in school and home controlled placements is a beneficial and inclusive opportunity for students, especially with ADHD ones.

In this context, more examinations of CAI effectiveness might be done. Concerns about sample size, educational settings or impact on other academic disciplines must be clarified. Moreover, other CAI or students' with ADHD characteristics could be included in studying computers' use effectiveness of interventions. New directions for studies on CAI effectiveness would benefit and strengthen the general suggestion of the studies reviewed, that is Computer-Assisted Instruction, has a potential to help students with disabilities improving their performance (Stetter & Hughes, 2010, p. 9) those with ADHD included.

References

1. Alper, S. & Raharinirina, S. (2006). Assistive technology for individuals with disabilities: A review and synthesis of the literature. *Journal of Special Education Technology, 21*(2), 47-64. doi: 10.1177/016264340602100204
2. American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders. Fifth edition (DSM-V)*. Washington, DC: American Psychiatric Pub.
3. American Psychological Association (2010). *Guidelines for nonhandicapping language in APA journals.* Retrieved 26/10/2017 from http://www.apastyle.org/manuals/related/nonhandicapping-language.aspx
4. *Andreou, G., Riga, A., & Papayiannis, N. (2016). Information and Communication Technologies and the impact of gender on the writing performance of students with ADHD. *Themes in Science and Technology Education*, *9*(1), 25-41. Retrieved from http://earthlab.uoi.gr/ojs/theste/index.php/theste/article/view/200/119.
5. Aslan, S., & Reigeluth, C. M. (2011). A trip to the past and future of educational computing: Understanding its evolution. *Contemporary Educational Technology, 2*, 1–17. Retrieved from http://www.cedtech.net/articles/21/211.pdf
6. Ayres, K. M., Mechling, L., & Sansosti, F. J. (2013). The use of mobile technologies to assist with life skills/independence of students with moderate/severe intellectual disability and/or autism spectrum disorders: Considerations for the future of school psychology. *Psychology in the Schools, 50*, 259–271. doi: 10.1002/pits.21673
7. Barkley, R. A. (2006). *Attention – Deficit Hyperactivity Disorder. A handbook for diagnosis and treatment*, 3rd ed. New York, NY: The Guilford Press.
8. Bayraktar, S. (2001). A meta-analysis of the effectiveness of computer-assisted instruction in science education. *Journal of Research on Technology in Education*, *34*(2), 173-188. doi: 10.1080/15391523.2001.10782344
9. Bender, R.L., & Bender, W.N. (1996). *Computer – Assisted Instruction for students at risk for ADHD, mild disabilities, or academic problems*, Boston, MA: Allyn & Bacon.
10. Benjamin, L. T. (1988). A history of teaching machines. *American Psychologist, 43*, 703–712. doi: 10.1037/0003-066X.43.9.703
11. *Bennett, D.E., Zentall, S.Z., 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.

12. Blok, H., Oostdam, R., Otter, M. E., & Overmaat, M. (2002). Computer-assisted instruction in support of beginning reading instruction: A review. *Review of Educational Research*, *72*(1), 101-130. doi: 10.3102/00346543072001101
13. *Bostian, A. (2011). *Effects of a computer-assisted intervention in second graders with attention and literacy problems*. (Master's thesis). Retrieved from http://thescholarship.ecu.edu/bitstream/handle/10342/3527/Bostian_ecu_0600M_10363.pdf
14. *Botsas, G. (2015). *Computer-Assisted Instruction of mathematical operations in ADHD and typical students. The online learning experience.* (Master's thesis. Aristotle's University of Thessaloniki). Retrieved from http://ikee.lib.auth.gr/record/269773/files/GRI-2015-14655.pdf
15. *Bouhouna, S. (2011). Computer's use and motivation on problem-solving tasks: The case of ADHD children. (Master's thesis. Aristotle's University of Thessaloniki) [in Greek]. Retrieved from http://ikee.lib.auth.gr/record/126229/files/GRI-2011-6479.pdf
16. Brand, S., Dunn, R., & Greb, F. (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
17. Carrier, M. L., Black, V., Vasquez, L., Miller, A.D., & Rosen, L.D. (2015). Executive function in risky online behaviors by adolescents and young adults. In L.D. Rosen, N.A. Cheever & L.M. Carrier (Eds.), *The Wiley handbook of psychology, technology, and society* (pp. 119-141). Chichester, West Sussex, UK: John Wiley & Sons.
18. *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.
19. *Cullen, J., Keesey, S., Alber – Morgan, S., & Wheaton, J. (2013). The effects of computer-assisted instruction using Kurzweil 3000 on sight word acquisition for students with mild disabilities. *Education and Treatment of Children, 36*(2), 87-103.
20. Daly, B. P., Creed, T., Xanthopoulos, M., & Brown, R. T. (2007). Psychosocial treatments for children with Attention – Deficit / Hyperactivity Disorder. *Neuropsychology Review, 17*, 73-89. doi: 10.1007/s11065-006-9018-2
21. *Doughty, T. T., Bouck, E. C., Bassette, L., Szwed, K., & Flanagan, S. (2013). Spelling on the fly: Investigating a pentop computer to improve the spelling skills of three elementary students with disabilities. *Assistive Technology*, *25*(3), 166-175. doi: 10.1080/10400435.2012.743491

22. DuPaul, G. J., & Eckert, T. L. (1997). 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
23. DuPaul, G. J., & Langberg, J. M. (2014). Educational impairments in children with ADHD. In R. Barkley (Ed.), *Attention-deficit/hyperactivity disorder: A handbook for diagnosis and treatment (4th ed.). New York: Guilford*.
24. DuPaul, G. J., & Stoner, G. (2003). *ADHD in the schools: Assessment and intervention strategies* (2nd ed.). New York: Guilford Press.
25. 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
26. DuPaul, G. J., & Weyandt, L. L. (2006). School-based intervention for children with attention deficit hyperactivity disorder: effects on academic, social, and behavioral functioning. *International Journal of Disability, Development and Education*, *53*(2), 161-176. doi: 10.1080/10349120600716141
27. DuPaul, G. J., Eckert, T. L., & Vilardo, B. (2012). The effects of school-based interventions for attention deficit hyperactivity disorder: a meta-analysis 1996-2010. *School Psychology Review*, *41*(4), 387-412.
28. Edybrun, D. L. (2013). Critical issues in advancing the special education technology evidence base. *Exceptional Children, 80*(1), 7-24. doi: 10.1177/001440291308000107
29. Fitzgerald, G, Fick, L., & Milich, R. (1986). Computer – Assisted Instruction for students with attentional difficulties. *Journal of Learning Disabilities, 19*(6), 376-379. doi: 10.1177/002221948601900614
30. Fitzgerald, G., Koury, K., & Mitchem, K. (2008). Research on computer-mediated instruction for students with high incidence disabilities. *Journal of Educational Computing Research*, *38*(2), 201-233. doi: 10.2190/EC.38.2.e
31. 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.
32. Fuchs, L. S., Fuchs, D., Hamlet, C. L., Powell, S. R., Capizzi, A. M., & Seethaler, P. M. (2006). The effects of computer-assisted instruction on number combination skill in at-risk first graders. *Journal of Learning Disabilities*, *39*(5), 467-475. doi: 10.1177/00222194060390050701
33. Gersten, R., Fuchs, L.S., Compton, D., Coyne, M., Greenwood, C. & Innocenti, M. E. (2005). Quality indicators for group experimental and quasi-experimental

research in special education. *Exceptional Children, 71*(2), 149-164. doi: 10.1177/001440290507100202

34. Graham, L. J. (2006). Caught in the net: A Foucaultian interrogation of the incidental effects of limited notions of inclusion. *International Journal of Inclusive Education*, *10*(1), 3-25. doi: 10.1080/13603110500173217
35. Gravois, T. A., & Gickling, E. E. (2002). Best practices in curriculum-based assessment. In A. Thomas & J. Grimes (Eds.), *Best practices in school psychology IV* (Vol. 2, pp. 885–898). Bethesda, MD: National Association of School Psychologists.
36. Hall, T. E., Hughes, C. A., & Filbert, M. (2000). Computer-assisted instruction in reading for students with learning disabilities: A research synthesis. *Education and Treatment of Children*, 173-193. Retrieved from http://www.jstor.org/stable/42940524
37. *Kang, H. W., & Zentall, S. S. (2011). Computer-generated geometry instruction: A preliminary study. *Educational Technology Research and Development*, *59*(6), 783-797. doi: 10.1007/s11423-011-9186-5
38. *Kingham, P.H., & Blackmore, A.M. (2003). Computer-based instruction in blending is effective for year 2 children with reading difficulties. *Australian Journal of Learning Disabilities, 8*(1), 30-37. doi: 10.1080/19404150309546721
39. Kolić-Vehovec, S. (2002). Effects of self-monitoring training on reading accuracy and fluency of poor readers. *European Journal of Psychology of Education, 17*, 129-138. doi: 10.1007/BF03173254
40. *Koscinski, S.T., & Gast, D.L. (1993). Computer – Assisted Instruction with constant time delay to teach multiplication facts to students with Learning Disabilities. *Learning Disabilities Research and Practice, 8*(3), 157-168. doi: 10.1177/002221949302600807
41. Kowalski, R. M., & Whittaker, E. (2015). Cyberbullying: prevalence, causes and consequences. In L.D. Rosen, N.A. Cheever & L.M. Carrier (Eds.), *The Wiley handbook of psychology, technology, and society* (pp. 142-157). Chichester, West Sussex, UK: John Wiley & Sons.
42. Kroesbergen, E. H., & Van Luit, J. E. (2003). Mathematics interventions for children with special educational needs: A meta-analysis. *Remedial and Special Education*, *24*(2), 97-114. doi: 10.1177/07419325030240020501
43. 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

44. 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
45. Lewandowski, L., Wood, W., & Miller, L.A. (2016). Technological applications for individuals with learning disabilities and ADHD. In J.K. Luiselli & A.J. Fischer (Eds.), *Computer-assisted and web-based innovations in psychology, special education, and health* (pp. 61-94). London, UK: Academic Press.
46. Liao, Y. K. C. (2007). Effects of computer-assisted instruction on students' achievement in Taiwan: A meta-analysis. *Computers & Education*, *48*(2), 216-233. doi: 10.1016/j.compedu.2004.12.005
47. Liu, M., Moore, Z., Graham, L., & Lee, S. (2002). A look at the research on computer-based technology use in second language learning: A review of the literature from 1990–2000. *Journal of Research on Technology in Education*, *34*(3), 250-273. doi: 10.1080/15391523.2002.10782348
48. *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 ADHD. *Journal of Attention Disorders, 9*(1), 301-312. doi: 10.1177/1087054705278832
49. *McClanahan, B., Williams, K., Kennedy, E., & Tate, S. (2012). A breakthrough for Josh: How use of an iPad facilitated reading improvement. *TechTrends, 56*(3), 20-28. doi: 10.1007/s11528-012-0572-6
50. McDuffy, K. (2009). Effectiveness of a computer literacy intervention for young children with attention and reading problems. (Master's thesis). Retrieved from http://thescholarship.ecu.edu/bitstream/handle/10342/2686/McDuffy_ecu_0600M_10093.pdf
51. Means, B., Penuel, W., & Padilla, C. (2001). *The connected school*. San Francisco, CA: Jossey-Bass.
52. *Nordness, P.D., Haverkost, A., & Volberding, A. (2011). An examination of hand – held computer-assisted instruction on subtraction skills for second-grade students with learning and behavioral disabilities. *Journal of Special Education Technology, 26*(4), 15-24. doi:10.1177/016264341102600402
53. *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
54. Pennington, R. C. (2010). Computer-assisted instruction for teaching academic skills to students with autism spectrum disorders: A review of literature. *Focus on*

Autism and Other Developmental Disabilities, *25*(4), 239-248. doi: 10.1177/1088357610378291

55. 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
56. *Regan, E., Berkeley, S., Hughes, M., & Kirby, S. (2014). Effect of computer-assisted instruction for struggling elementary readers with disabilities. *The Journal of Special Education, 48*(2), 106-119. doi: 10.1177/0022466913497261
57. *Reid, M. S. (2000). *The effects of teacher-and computer-directed instruction on children with attention-deficit/hyperactivity disorder (AD/HD)* (Doctoral dissertation). Available from ProQuest Dissertations and Theses Database (UMI No. 9973918).
58. Rieth, H. J., & Semmel, M. I. (1991). Use of computer-assisted instruction in the regular classroom. In G. Stoner, M. R Shinn, & H. M. Walker (Eds.), *Interventions for achievement and behavior problems* (pp. 215-239). Silver Spring, MD: National Association of School Psychologists.
59. Schmidt, M., Weinstein, T., Niemiec, R., & Walberg, H. (1985–1986). Computer-based instruction and exceptional children: A meta-analysis of research findings. *Journal of Special Education, 19*, 493-502.
60. Schoonen, R., van Gelderen, A., de Glopper, K., Hulstijn, J., Simis, A., Snellings, P., & Stevenson, M. (2003). First language and second language writing: The role of linguistic knowledge, speed of processing, and metacognitive knowledge. *Language Learning*, *53*(1), 165-202. doi: 10.1111/1467-9922.00213
61. Seo, Y. J., & Bryant, D. P. (2009). Analysis of studies of the effects of computer-assisted instruction on the mathematics performance of students with learning disabilities. *Computers & Education*, *53*(3), 913-928. doi: 10.1016/j.compedu.2009.05.002
62. *Shaw, R., & Lewis, V. (2005). The impact of computer-mediated and traditional academic task presentation on the performance and behavior of children with ADHD. *Journal of Research in Special Educational Needs, 5*(2), 47-54. doi: 10.1111/J.1471-3802.2005.00041.x
63. Skinner, B. F. (1958). Teaching machines. *Science, 128*, 969-977.
64. 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
65. *Slate, S.F., Meyer, T.L., Burns, W.J., & Montgomery, D. D. (1998). Computerized cognitive training for severely emotionally disturbed children with ADHD. *Behavior Modification, 22*(3), 415-437. doi: 10.1177/01454455980223012

66. Slavin, R.E., & Lake, C. (2008). Effective program in elementary mathematics: A best-evidence synthesis. *Review of Educational Research, 78*(3), 427-515. doi: 10.3102/0034654308317473
67. *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. doi: 10.1353/etc.2011.0011
68. Soe, K., Koki, S., & Chang, J. M. (2000). *Effect of Computer-Assisted Instruction (CAI) on Reading Achievement: A Meta-Analysis*. (ERIC ED 443079). Retrieved from http://files.eric.ed.gov/fulltext/ED443079.pdf
69. *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.
70. Sousa, D.A., & Tomlinson, C.A. (2011). *Differentiation and the brain*, Bloomington, IN: Solution Tree Press.
71. Stetter, M. E., & Hughes, M. T. (2010). Computer-assisted instruction to enhance the reading comprehension of struggling readers: A review of the literature. *Journal of Special Education Technology*, *25*(4), 1-16. doi: 10.1177/016264341002500401
72. *Tattrie, L. (2003). Teaching mathematics to children with attentional difficulties. Computer-assisted instruction versus small group instruction. (Master's thesis). Available from ProQuest Dissertations and Theses database (UMI No 305234402).
73. Touroutoglou, A., & Efklides, A. (2010). Cognitive interruption as an object of metacognitive monitoring: Feeling of difficulty and surprise. In A. Efklides & P. Mihailidi (Eds.), *Trends and prospects in metacognition research* (pp. 171-208). New York, NJ: Springer. doi: 10.1007/978-1-4419-6546-2
74. Walcott, C.M., Marett, K. & Hessel, A. (2014). Effectiveness of a Computer-Assisted Intervention for young children with attention and reading problems. *Journal of Applied School Psychology, 30*(2), 83-106. doi: 10.1080/15377903.2013.87438
75. Xu, C., Reid, R., & Steckelberg, A. (2002). Technology applications for children with ADHD: Assessing the empirical support. *Education and Treatment of Children, 25*, 224-248. Retrieved from http://www.jstor.org/stable/42900528

76. Zentall, S. S. (2006). *ADHD and education: Foundations, characteristics, methods, and collaboration.* Upper Saddle River, NJ: Prentice Hall.
77. Ziegler, D. A., Mishra, J., & Gazzaley, A. (2015). The acute and chronic impact of technology on our brain. In L.D. Rosen, N.A. Cheever & L.M. Carrier (Eds.), *The Wiley handbook of psychology, technology, and society* (pp. 3-19). Chichester, West Sussex, UK: John Wiley & Sons.