The impact of computer-mediated and traditional academic task presentation on the performance and behaviour of children with ADHD

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Key words: computer-mediated communication, ADHD performance and behaviour.

This project aimed to examine whether the use of computers could have a positive impact on the performance of academic tasks and their behaviour whilst completing them of children with ADHD. This small exploratory study therefore 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. The effects of these different forms of computer presentation were examined in relation to performance on more traditionally presented, pen and paper, tasks. The results of this study revealed that, in contrast to typically developing children, participants with ADHD produced the greatest number of accurate responses on the more basic computerised tasks (presented as simple Microsoft Word documents) and exhibited significantly more on-task activity on animated computerised tasks. In summary, computerised presentation significantly improved the accuracy of responses and the on-task focus of participants with ADHD. These early findings are encouraging and may have wide reaching practical implications in terms of the design and implementation of educational software aimed at promoting improvements for children with ADHD in terms of both their academic performance and, critically, appropriate on-task focus and behaviour in the classroom.

It is estimated that in every 100 children, between three and five are diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). Symptoms of hyperactivity, impulsivity and inattention are at the heart of the disorder (APA, 1994) and co-occurring disorders are common for children with ADHD. Children with ADHD consistently underachieve academically, with at least 50 percent failing annual school exams by adolescence (Zentall, 1993). Barkley (1997b) reported a 90 percent likelihood of school failure and a 50 percent likelihood of underachievement in employment for individuals with ADHD (Barkley, 1990; Weiss & Hechtman, 1993). In many cases medication is resorted to and often this can help to increase attention and improve behaviour. However, research suggests that medication is most effective when used in combination with other forms of behaviour management and classroom interventions. As a result research continues into a range of different classroom-based interventions.

Anecdotal reports (Barkley, 1997a; Nash, 1994; Serfontein, 1990) and exploratory investigations of parental observations (Shaw, Grayson & Lewis, 2001; 2002) have described a range of abilities displayed by children with ADHD while engaging with computer games that are extremely encouraging and suggest that new technologies may provide practical new opportunities for the enhancement of classroom behaviour and performance. The findings of Shaw, Grayson and Lewis’s research suggest that to increase the chances of a child with ADHD of maintaining concentration and attention and of withholding impulsive responses and inappropriate behaviours, the child needs to be specifically motivated and stimulated and this is where the use of computers appears to be critical.

This project aims therefore aims to examine systematically whether the use of computers could also have a positive impact on performance of academic tasks and their behaviour whilst completing them of children with ADHD. There are several key research questions to be examined. These include:

• Does computer-mediated presentation of academic tasks lead to better performance and behaviour for children with ADHD than paper and pencil tasks?
• Does the inclusion of narratives, reinforcement strategies and coloured characters in the presentation of academic tasks lead to better performance and behaviour for children with ADHD?
• Is the effect of computer task presentation and additional stimulating features on performance similar in children with ADHD and typically developing children?

Based on this anecdotal evidence and Shaw, Grayson and Lewis’s earlier research findings, the following predictions can be made that:

• there will be a difference in the performance and behaviour of children with ADHD across tasks presented in these different media formats;
• computerised presentation of tasks will enhance performance and behaviour;
• the addition of features including cartoon character, animation and a scoring system will enhance performance and behaviour;
• there will be no difference in the performance and behaviour of typically developing participants across tasks presented in these different media formats.

Method
Participants
A total of twenty children with ADHD and twenty typically developing children participated in the study. These children were matched as closely as possible on general experience with computers, and on their full-scale IQ score (FSIQ) and reading age (RA). Three participants in each group were female, and seventeen male. The age of participants with ADHD ranged from 7 years 0 months to 12 years 3 months with a mean age of 9 years and 9 months (SD 1.67). The age of typically developing participants ranged from 7 years 0 months to 12 years 7 months with a mean age 9 years 10 months (SD 1.66).

Children with ADHD met the criteria for ADHD based upon the Diagnostic and Statistical Manual of Mental Disorders (APA, 1994) and the clinical cut offs on the Achenbach Child Behavior Checklist (Achenbach, 1991) and the Achenbach Teacher’s Report Form (Achenbach, 1977). Just over half of the children with ADHD had co-occurring disorders, including Anxiety (3), Conduct Disorder (CD) (2), Dyslexia (2), Development Co-ordination Disorder (DCD) (2), Obsessive Compulsive Disorder (OCD) (1), Oppositional Defiance Disorder (ODD) (1) and Semantic Pragmatic Language Disorder (SPLD) (1). The characteristics of the ADHD and typically developing (TD) groups are summarised in Table 1.

The tasks
Participants were presented with four Key Stage 2 science tasks. These were presented in pen and paper workbook format and in computer-mediated workbook format. Children were required to write (pen and paper workbook) or type (electronic workbook) their answers to 10 questions. Both forms of the workbook were presented with and without the addition of a narrative, reinforcement and coloured character. The four formats were as follows:

- Pen and Paper: A pen and paper workbook consisting of 10 science-based questions with multiple choice answers. Information, instructions and questions were type written and participants were required to indicate their answer by ticking the relevant box on the answer sheet.
- Pen and Paper with Animation: A pen and paper workbook consisting of 10 science-based multiple choice questions. This was also typewritten and required participants to tick the appropriate box to indicate their answer. However, all narratives, information, instructions and questions were presented by a colourful cartoon character (in speech bubbles). This character informed the participant that his or her work would be scored and that feedback would be given by the ‘helper’ (the experimenter).
- Computerised: A computer-based workbook consisting of 10 science-based questions with multiple choice answers, presented in Microsoft Word format. Participants were required to scroll through the workbook using the keyboard and mouse as demonstrated by the experimenter. Information, instructions and questions were typewritten and participants were required to indicate their answer by using the mouse to tick the relevant box on the answer sheet.
- Computerised with Animation: A computer-based ‘interactive’ workbook consisting of 10 science-based multiple choice questions. Participants were required to scroll through the workbook using the mouse and by clicking appropriate icons on the screen. This was also typewritten and required participants to tick the appropriate box, using the mouse, to indicate their answer. However, all narratives, information, instructions and questions were presented audio visually by a colourful cartoon character (in speech bubbles and the character ‘spoke’ to the participant). This character informed the participants that their work would be scored and that he would give them feedback at the end of the session.

Table 1: Characteristics of ADHD and typically developing participants in terms of Age, FSIQ Score, Reading Age and General level of experience on computers

<table>
<thead>
<tr>
<th></th>
<th>Mean Age (years) (SD)</th>
<th>Mean FSIQ (SD)</th>
<th>Mean Reading Age (SD)</th>
<th>Mean Level of Experience with Computers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD</td>
<td>9.9 (1.67)</td>
<td>106.4 (11.21)</td>
<td>10.1 (2.07)</td>
<td>Experienced</td>
</tr>
<tr>
<td>TD</td>
<td>9.10 (1.66)</td>
<td>109.8 (10.82)</td>
<td>10.3 (2.02)</td>
<td>Experienced</td>
</tr>
</tbody>
</table>

Procedure
Before participants were presented with the tasks they were assessed using the Wechsler Abbreviated Scales of Intelligence (WASI) (The Psychological Corporation, 1999) and the British Ability Scales II Word Reading Card (Elliott, 1996).

All participants with ADHD abstained from taking medication 4 hours prior to testing. They resumed their medication as soon as testing finished. However, residual methylphenidate may have affected performance. Participants’ parents and consultants had agreed to this arrangement for this study. All participants completed the tasks in an informally furnished room that contained distracting objects, including a computer, books and toys.

Participants were asked to rate their level of experience on computers (see Table 1). Consultation with parents was
used to confirm level of experience. Participants were asked if they would like to help the experimenter again by completing some work on the laptop and in workbooks. Participants were then presented with the four Key Stage 2 tasks. The order of the tasks was counterbalanced.

For each task the experimenter explained ‘I am going to give you a workbook. It contains some information and questions about some of the things you might have been studying in science lessons. I would like you to read the information and then answer the questions by ticking the box next to the answer you choose. You can take as long as you like to complete the workbook. I will be sitting at the back of the room. You can let me know when you have finished or if you would like to stop at any time’.

For each of the Animated Tasks the experimenter also explained that their work would be marked and that their score would be given to them at the end of the session.

After receiving the task’s instructions the experimenter made sure that the participants had understood the instructions for the task and how to fill in the workbook. For the computerised tasks the experimenter demonstrated the controls for the laptop and asked the participants to show that they were able to move the mouse and appropriate icons with sufficient proficiency to complete the task. All participants demonstrated a high degree of skill with the laptop’s controls. All participants had rated themselves as being experienced with computers. Participants were then left to complete the first task. After each task was completed the experimenter returned to the children and thanked them for their participation. For the Animated tasks participants were then given their score. Participants were then asked if they would like to complete the next task. On completion of the last task participants were complimented on their performance and thanked for their participation.

**Coding**

Performance was coded according to the number of correct responses made. Each task contained a total of 10 questions and therefore could score a potential 10 points per task. On-task activity was recorded using a 10-second interval recording system by the experimenter from an unobtrusive location at the back of the room. A video camera or web cam also recorded the activity. Random selections of the video recordings were rated using the 10-second interval system by an independent observer.

**Results**

**Performance data**

In order to examine performance the number of correct responses produced by both groups of participants was examined. The mean number of correct responses and their standard deviations (SD) produced on the four tasks are presented in Table 2.

A mixed ANCOVA conducted on these data, using full scale IQ (FSIQ) scores and reading age (RA) as covariates, did not reveal a statistically significant effect of group (F(1,46) = 0.602; \( P = 0.442 \)). However, a statistically significant effect of task was observed (F(3,138) = 3.129; \( P = 0.028 \)). A significant interaction between group and task was also observed (F(3,138) = 2.704; \( P = 0.048 \)). The nature of this interaction is shown in Figure 1.

A one-way ANCOVA, conducted to test the prediction that there would be a difference in the performance of participants with ADHD across the different forms of presentation, revealed a significant difference in performance across tasks (F(3,66) = 3.060; \( P = 0.034 \)). Planned comparisons, conducted in order to test the prediction that participants with ADHD would produce the greatest number of correct responses on the computerised tasks, and in particular on the Computerised with Animation task, revealed a significant difference in correct responses across the Computerised task compared to the Pen and Paper Task (F(1,16) = 6.708; \( P = 0.01 \)). Contrary to prediction, the addition of cartoon characters, animation, and a scoring system did not enhance performance to a greater degree than basic computerisation. Furthermore, the addition of cartoon characters and a scoring system to the pen and paper tasks did not appear to greatly enhance the performance of participants with ADHD.

In contrast, and as predicted, a one-way ANCOVA conducted on the data produced by typically developing participants did not reveal a significant difference in error making across the four tasks (F(3,66) = 1.055; \( P = 0.374 \)). As a result, further

<table>
<thead>
<tr>
<th>Task</th>
<th>Pen and Paper</th>
<th>Pen and Paper with Animation</th>
<th>Computerised</th>
<th>Computerised with Animation</th>
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<tr>
<td>ADHD (SD)</td>
<td>5.24 (2.60)</td>
<td>5.36 (2.51)</td>
<td>6.56 (2.21)</td>
<td>6.12 (2.29)</td>
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<tr>
<td>TD (SD)</td>
<td>6.12 (2.78)</td>
<td>6.64 (2.67)</td>
<td>6.04 (1.69)</td>
<td>6.32 (2.64)</td>
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Figure 1: Correct responses produced by participants with ADHD and typically developing participants on the Pen and Paper, Pen and Paper with Animation, Computerised and Computerised with Animation Key Stage 2 science tasks
analyses comparing performance across computerised and animated tasks were not conducted.

To give an indication of whether co-morbid disorders were having any systematic effects on the data for the children with ADHD, a mixed ANCOVA was conducted. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and performance on these four tasks (F(1,18) = 0.244; \( P = 0.627 \)).

**Observations**

Observations were made of on-task and off-task behaviour using a 10-second interval procedure. The participant was recorded as being ‘on-task’ for any given 10-second interval providing off-task behaviour occurred for no more than three consecutive seconds. As soon as a participant spent more than three consecutive seconds attending to or engaging with something else (rated as distracted behaviour, touching an object in the room, fidgeting or out of seat behaviour), their behaviour for that given ten seconds was recorded as ‘off-task’. Inter-rater reliability on a sample of just over 10 per cent of the observations was assessed using Cohen’s Kappa (Cohen, 1960). A value of \( k = 0.000 \) was observed.

The total amount of time taken to complete the task was recorded and the percentage of time spent on task calculated. The mean number of 10-second intervals spent by participants engaging in on-task activity while completing the four Key Stage 2 science tasks is recorded in Table 3.

A mixed ANCOVA conducted on the data produced by ADHD and typically developing participants (using FSIQ and RA as covariates) revealed a significant effect of group (F(1,46) = 94.40; \( P < 0.001 \)) and task (F(3,138) = 2.99; \( P = 0.033 \)) on the number of 10-second intervals spent on-task. This analysis also revealed a significant interaction between group and task (F(3,138) = 8.68; \( P = 0.001 \)). The nature of this interaction can be seen in Figure 2.

In order to test the prediction that participants with ADHD would perform differently across the tasks, a one-way ANCOVA was conducted on the data produced by the participants with ADHD. This revealed a significant difference in on task activity across the tasks (F(3,48) = 3.339; \( P = 0.027 \)).

Planned comparisons, conducted to test the prediction that participants would exhibit more on-task activity on the computerised Key Stage 2 science tasks compared to the pen and paper tasks and on the animated compared to non animated tasks, indicated that both computerisation and animation increased the amount of on-task activity exhibited by these participants. Significant differences were observed between the on-task activity exhibited on the Computerised compared to Pen and Paper with Animation tasks (F(1,16) = 7.219; \( P = 0.016 \)) and the Computerised with Animation and the Pen and Paper with Animation Tasks (F(1,16) = 6.736; \( P = 0.020 \)).

As predicted, typically developing participants performed similarly on all tasks and a one-way ANCOVA conducted on these data did not reveal any significant differences in on-task activity across tasks (F(3,66) = 0.422; \( P = 0.738 \)). As a result, further analyses comparing on-task activity across computerised and animated tasks were not conducted.

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANOVA was conducted on them. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on these four tasks (F(1,18) = 1.083; \( P = 0.312 \)).

**Discussion**

The results of this study have shown improvements in error making and in on-task behaviour for children with ADHD under specific conditions. Typically developing participants produced fewer errors in the animated pen and paper format and the greatest errors in the basic computerised format. In contrast, participants with ADHD produced the fewest amount of errors in the basic computer format, as predicted, but contrary to prediction, the greatest errors in the animated computer format. Children with ADHD reported that the amount of activity in animated computer format sometimes

<table>
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<th>Table 3: Mean number of 10-second intervals spent engaging in on-task activity while completing the Pen and Paper, Pen and Paper with Animation, Computerised and Computerised with Animation Key Stage 2 science tasks</th>
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<td></td>
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distracted them from paying attention to the information given. In addition, during the animated computerised tasks participants were required to listen to information presented by the animated character before they could start answering the questions. Many of the participants with ADHD reported that they found this frustrating and just wanted to get on with the task at their own pace or move directly to the questions. Either of these factors might account for greater errors. This desire to just ‘get on with it’ may seem somewhat predictable and typical of the attitude of children with ADHD bearing in mind the level of impulsivity associated with the condition (APA 1994; Barkley, 1997a).

Improvements in on-task behaviour for both groups have also been seen, with typically developing participants exhibiting slightly more on-task behaviour for animated versions, first the on the pen and paper and second on the computerised versions of the tasks, and fewest on task activity for the non-animated tasks. The on-task performance of typically developing children reflected their performance in terms of correct responses, with the greatest number of correct responses occurring on the task for which they exhibited the most on-task activity. In contrast participants with ADHD exhibited significantly less on-task behaviour for the pen and paper formats and more on-task behaviour on the computerised tasks, with the greatest improvements on the animated computerised presentation. The on-task activity of participants with ADHD did not correspond to their performance in terms of correct responses.

Findings were as predicted following previous studies: computerised presentation significantly improved on-task focus of participants with ADHD. The performance of children with ADHD was again found to be context dependent. In particular, children with ADHD responded favourably to the presentation of educational tasks on a computer. Contrary to expectation, the addition of the features associated with computer games, that is, animated characters, immediate reinforcement, narratives and colourful interactive environments, were not necessary for encouraging these performance enhancements in terms of an increase in the accuracy of responses. Critically, just by presenting information on a computer in a basic word processed format improvements in the accuracy of the responses of participants with ADHD occurred. This is particularly encouraging for the education of children with ADHD as access to such a practical and user-friendly intervention would not require specialist programming or computing expertise.

In contrast, the addition of the features allied with computer games (animated characters, narratives, feedback and colourful graphics) did seem to be important for encouraging greater on-task activity of participants with ADHD.

There are several important implications concerning the impact of changes in task context that can be drawn from this research. In general these contextual features may be the types of criteria that may help the child to make greater sense of the task, making it more interesting and desirable. Interestingly, although the computerised animated tasks were the most sophisticated in terms of graphics and interactivity this task did not produce the greatest enhancement in accuracy of responses for participants with ADHD. This would suggest that there is something more than the visual and auditory characteristics, or ‘packaging’ of the task that were of importance in terms of performance enhancements. Perhaps the structure of the task, its storyline, characters and goals are more important. These features might certainly help to make the game make sense to the player.

The role of motivation, arousal and effort

According to some of the leading theoretical accounts of ADHD, symptoms of the condition are attributed to a combination of pervasive biological and neurological influences that impact on cognition and behaviour. However, the findings of the present research point to the need to consider how these neurobiological deficits might interact with environmental influences. These research findings provide evidence for a specific interaction between the contextual features associated with computerisation of tasks and the condition known as ADHD. Perhaps the first feature of computerisation that one must consider is the level of interest and motivation that it might stimulate in the child. It would seem obvious that an increase in interest might stimulate greater performance, but there are additional reasons why this might be particularly important for individuals with ADHD. Features that increase an individual’s interest and motivation are likely also to increase effort and arousal (Zentall, 1975; Zentall and Meyer, 1987; Zentall and Zentall, 1983) and there is considerable empirical evidence to suggest that pervasive deficits of motivation, arousal, activation and effort are at the heart of ADHD. For example, Optimal Stimulation Theory proposes that the problems associated with ADHD occur as a result of under stimulation and failure to reach the optimal level of physiological arousal required to complete tasks (Zentall, 1975; Zentall and Meyer, 1987; Zentall and Zentall, 1983). Others have suggested that the behaviours that typify ADHD occur as a result of an underlying deficit of different energetic states, each of which is thought to be influenced by motivational factors (Pribram & McGuiness, 1975; Sanders, 1983; Sergeant & van der Meere, 1990). van der Meere, Hughes, Borger and Sallee (1995) referred to ADHD as a problem of non optimal activation and effort and Antrop, Roeyers, Van Oost and Buyssse (2000) described how failure to reach optimal stimulation results in stimulation seeking behaviour as individuals with ADHD try to compensate for low levels of cortical arousal. This accounts for the types of off-task behaviours commonly exhibited by children with ADHD when asked to complete tasks in the classroom. However, of importance to this study is the assumption that if state factors are manipulated by contextual changes, then, given the correct degree of incentive, increased activation and effort result in increases in cortical stimulation and thus improvements in performance.

Thus, it is clear that the impact of motivation on on-task activity and performance requires careful consideration. However, could motivation also distract from main aim of
task? This could certainly offer an explanation with regard to the performance of participants with ADHD on the animated computerised tasks. Could participants with ADHD have been over stimulated and therefore over responded? Perhaps participants with ADHD experienced problems in remembering the main aim of the task in presence of more interesting stimuli? Or perhaps processing resources were allocated to more interesting surface features or distractions and not to task content? The sensitivity of participants to the type of reinforcement given in the tasks also needs to be considered. Douglas and Parry (1983) suggested that individuals with ADHD are over sensitive to rewards. Some evidence to support this theory was found, with results suggesting that individuals with ADHD are sensitive to both reward and cost. Error making decreased for all participants on tasks where scores were given.

**Characteristics of computerisation?**

But why computers? What do they offer beyond the stimulation that they provide? What characteristics of basic computerised task presentation could have enhanced the performance of participants with ADHD? Perhaps it is because computers allow children to work at their own pace, or perhaps it is because computers do not rely on handwriting skills and have inbuilt mechanisms to help children regulate or manipulate their own performance, such as spell checks, thesaurus, grammar checks, cut and paste buttons, and so on. Perhaps it is because computers allow children to work in a more contained and private manner, they can just delete work and have no record of mistakes, and their work is less accessible to others than when on pen and paper. Perhaps it is something to do with the child’s perception of computers, perhaps they are seen as more exciting, or special? Or perhaps children with ADHD are simply more confident in using computers because of previous successes on computer games. Shaw, Grayson & Lewis (2001; 2002) examined parental reports of the interests of children with ADHD and typically developing children and their behaviours while playing computer games. Parents of children with ADHD believed their children show a specific interest in computers because they are fast moving, colourful, interactive and challenging.

In contrast to parents of typically developing children, the majority of parents of children with ADHD reported that the constant stimulation provided by computer games contributes to the interest of their child with ADHD and they felt that fast games were those that were not only enjoyed the most by their children with ADHD, but were also those that facilitated more successful performance and better attention. Some parents of children with ADHD reflected upon the fact that computer settings are one of a few contexts in which their child with ADHD feels they are successful. These parents also indicated that the element of control was, in their opinion, an important factor, particularly in terms of choice of when to play, what to play, when to stop, and the fact that this is not a task imposed by adults. This appeared to overlap with comments concerning the belief that computer games are the ‘property’ of children, that parents do not understand them or know how to play.

Perhaps then, it is also associations made by the ‘social’ context that drives participants with ADHD more then typically developing participants? One hypothesis is that meaningful and salient framing of tasks facilitates successful performance as contextual cues implicitly guide behaviour. This is illustrated by Ceci and Roazzi’s finding that certain contexts help children to demonstrate abilities not generally seen in ‘disembedded’ laboratory contexts. They stated that:

> ‘For instance, a task is perceived as a video game it may help recruit a set of strategies that children have acquired to conquer video games that might not be recruited if the same task is perceived a type of test’.
> (Ceci & Roazzi, 1994, p. 77)

To date there appears to be relatively little research that addresses the impact of framing tasks as computer games on the cognitive performance of children. Underwood, McCaffrey & Underwood (1990), however, have examined computer-based interactions between children and discuss how gender seems to be one of the most constant determinants of performance, possibly because of perceptions of male expertise and lower levels of female confidence, and this observation is certainly stressed by the research outlined by Littleton and Light (1999), and by Light, Littleton, Bale, Joiner & Messer (2000) and Keogh, Barnes, Joiner & Littleton (2000). Exploration of the role of the computer in these interactions has generally concluded that the type of structure and feedback offered in this context might be of significance. Howe and Tolmie (1999) hypothesised that computers are important as they can provide an environment for action based learning while also giving unambiguous feedback. In addition, Säljö (1999) describes how computers offer the opportunity for greater visualisation, or representation, of all sorts of complicated types of conceptual knowledge or phenomena. This also allows knowledge to be manipulated in ways that might otherwise be impossible. This can provide greater opportunity for trial and error in ‘safe’ environments. In short, Säljö (1999) argues that computers can help make the abstract more tangible.

To summarise, this study stresses the potential importance of computer-based contexts that appear to have been successful in facilitating improvements in both performance and behaviour. As Littleton (1999) stresses, the expectations of the computer user can be ‘powerful mediators’ of activity. This aspect of interaction with computers is certainly one that is likely to impact on the performance of children on computerised tasks and games. The information presented here suggests that careful consideration be made of the potential impact of computers on performance. In conclusion, these early findings are therefore both positive and constructive and may have wide reaching practical implications in terms of the design and implementation of educational software aimed at promoting improvements for children with ADHD in terms of both their academic performance and, critically, appropriate on-task focus and behaviour in the classroom.
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