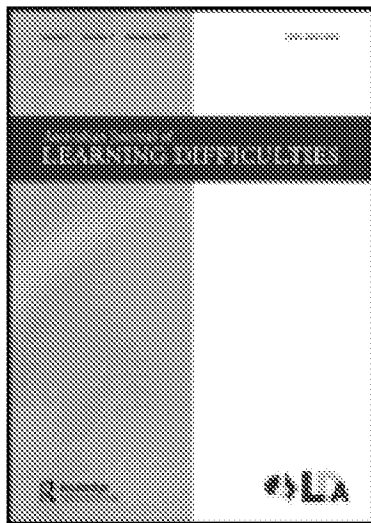


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Reducing the effects of auditory and visual distraction on the math performances of students with Attention Deficit Hyperactivity Disorder

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Two exploratory studies assessed the effects of an intervention on the math problem solving of students with Attention Deficit Hyperactivity Disorder (ADHD). In the first study, students were assessed on a visual task in a high stimulation classroom analog setting with and without the use of a fine motor activity. Results showed that the fine motor activity was associated with more math problems correct. In the second study, students were presented with a visual task with and without auditory distraction. Results showed that the auditory distraction impeded performance but that the fine motor activity mitigated the effects of the distraction. Although the results of these studies are modest, they suggest that fine motor activity may affect the performances of students with ADHD and future research is needed.

Introduction

Students with Attention Deficit Hyperactivity Disorder (ADHD) have difficulty sustaining attention to their tasks and have been reported to display between three and eight times as many off-task behaviors as comparison students (Carroll et al., 2006). Maintaining and directing ones attention is necessary to effectively process information and solve complex problems, such as math story problems. In an examination of triggers, Carroll et al. reported that the solitary off-task behaviors and vocalizations of 3–8-year-old children with ADHD were mainly attributed to environmental distractions (e.g. noise and movement outside the classroom) and teacher-initiated distractions (e.g. giving multiple or confusing instructions). Solitary off-task behaviors increased as environmental distractions increased.

The ability to sustain attention in the presence of distraction is considered one of a series of activities that facilitate goal-directed behavior (Barkley, 2000). For adaptive behavior it is necessary to allow oneself to become distracted by important environmental stimulation but, once distracted, reorient attention to the task (Wetzel, Berti, Widmann, & Schroger, 2004). Sustaining attention requires the active maintenance of stimulus priorities in working memory (de Fockert, Rees, Frith, & Lavie, 2001).

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It is not clear whether students with ADHD are more susceptible to the effects of distraction than are students without disorders. Prinz, Tarnowski and Nay (1984) reported that children with ADHD have generalized deficits on tasks requiring sustained attention but are not differentially susceptible to the effects of distraction, assessed during a repetitive, vigilance task. But, in environmentally distracting conditions, Klein and Young (1979) found that students with ADHD spent less time on their tasks than did students without ADHD. Conversely, Zentall and Zentall (1976) reported that students with ADHD were less hyperactive and performed better on a low-level task in a high-stimulation environment than in a low-stimulation environment. Apparently the stimulating environment was not distracting and facilitated task completion.

It may be that distraction effects vary depending on the complexity of the task. Berti and Schroger (2003) reported that distraction effects were lower for university students in a high-load condition than a low-load one, suggesting that we focus our attention more during difficult tasks and are better able to screen out distractions. But French, Zentall and Bennett (2003) reported that when children with ADHD were exposed to distraction while being required to hold information in working memory and manipulate or order that information (a complex task), they performed worse than comparisons on the recall of information. Working memory is used to reduce the effects of distraction by holding the prioritization of relevant information. It may be that students with ADHD have difficulty holding and manipulating information in high load situations and are not able to override the effects of distraction with more focused attention.

Children with ADHD do not show deficits in memory performance on simple, serial recall tasks (Roodenrys, Koloski, & Grainger, 2001). It is only in complex tasks, when they are required to order or update information, that children with ADHD show a memory deficit. Karatekin (2004) reported that the working memory impairments of children with ADHD may be due to impairments in the central executive component of working memory that controls the ability to divide attention between two demands.

Based on this literature, we conclude that students with ADHD can be predicted to have difficulty with complex tasks that require them to mentally hold and manipulate information. We also predict that additional distraction should impair their performance during these tasks. These predictions can be interpreted through the optimal stimulation theory that proposes that all humans have a biologically determined need for an optimal level of stimulation and, when there is insufficient stimulation, will initiate stimulation-seeking activity to create a state of homeostasis (Hebb, 1955). Homeostasis refers to an individual's maintenance of his or her internal environment within tolerable limits (Saul, 1998). Application of the optimal stimulation theory to students with ADHD provides an understanding of their inability to sustain attention. That is, due to their under-reactivity to the levels of stimulation in normal environments, these students activate a wide focus of attention that allows them to take in as much stimulation as possible, which can interfere with task completion (Zentall, 2006). So, when engaging in a complex task that requires students to hold and manipulate information in memory, students with ADHD are challenged. Additionally, when under-stimulated, they look around the room and attend to salience to increase their stimulation and physical comfort levels, further challenging their attention to their tasks.

Improvements in sustained attention for students with ADHD have been observed with stimulant medication (Barkley, 1977). Self-regulation methods (e.g. self-talk, self-instruction, self-monitoring, self-reinforcement) have also been used with some success (see Ervin, Bankert, & Dupaul, 1996) but these methods may place additional demands on attention during a problem solving task. During academic tasks requiring concentration, students with ADHD have been observed engaging in a variety of fine motor activities (e.g. hair twirling, nail biting, chewing on objects) that may function to generate and regulate stimulation and allow them to narrow their focus of attention and concentrate on their tasks (Grskovic, 2000). Kercood, Grskovic, Lee and Emmert (2007) assessed the effects of a fine motor activity used for stimulation regulation during math problem solving tasks on the performance and behavior of students with ADHD and found that the fine-motor activity facilitated task completion and accuracy. Their assessment took place in an empty classroom rather than in a typical one.

Methods

Because of the contribution of environmental stimulation to the attention problems of students with ADHD, the purpose of Study 1 was to assess the effects of a fine-motor activity on math problem solving in an analog classroom environment. This type of setting was used in both studies to simulate the distractions and stimulation levels found in typical elementary classrooms. An analog setting was used to avoid competing task demands that might arise in the actual classroom. Students were asked to listen to taped math problems and give verbal answers. We were interested in determining if the fine-motor activity could help students with ADHD attend to their challenging math task in the presence of typical classroom stimulation.

In Study 2 a changing-conditions design was used to assess the effects of the fine-motor activity on math problem solving when additional auditory distractions were introduced. Performances were assessed under four conditions: (1) baseline, (2) distraction, (3) distraction plus fine motor activity and (4) fine motor activity without distraction. Tasks were presented visually with verbal distractions. We were assessing if the fine-motor activity could help students with ADHD reorient to their task after distraction.

Study 1

This study employed an alternating treatments design to assess the effects of a fine-motor activity on math problem solving in a visually complex, typical classroom environment.

Participants and setting

Three 10-year-old students with average IQ, two fourth graders and one fifth grader, participated in this study. Participants were all English-speaking and attended school in the USA. They are referred to in this paper as Tom, Julian and Lenny (pseudonyms). All three had been diagnosed with ADHD and were on stimulant medication. Tom and Julian were also diagnosed with learning disabilities. Their ADHD status was confirmed with parent and teacher rating on the Conner's Rating

Table 1. Scores on the Conner's Rating Scale, Study 1.

	Teacher ratings			Parent ratings		
	Lenny	Julian	Tom	Lenny	Julian	Tom
Cognitive/Problems/Inattention	54	74	52	*	70	*
Hyperactivity	76	64	56	*	72	*
Conners ADHD Index	72	68	55	*	75	*
Conners Global Restless Impulsive	73	73	52	*	69	*
DSM-IV Inattentive	65	69	54	*	73	*
DSM-Hyperactive Impulsive	76	55	52	*	78	*
DSM-IV: Total	69	64	53	*	77	*

Note: Scores are *t*-scores with a mean of 50 and standard deviation of 10; *scores were unavailable; rating scales were not returned.

Scale. Scores are presented in Table 1. The Table shows that Lenny and Julian were viewed by either parents or teachers as inattentive and hyperactive, whereas Tom was not seen by his teacher as demonstrating impairments at the time, possibly due to the effectiveness of his stimulant medication. His parents failed to return their ratings.

Procedures

Math story problems with similar reading levels were selected from fourth grade texts for the assessment. The math problems contained one and two operations and were equivalent based on the structure, number of words, operations and complexity. For each session, 20 problems were read aloud by a female and were recorded onto audio tape. There was a 20-second pause between each math problem after which the recording automatically moved on to the next problem.

Participants were assessed one at a time in an empty classroom in their elementary school. The room had been decorated with colorful posters and educational materials to simulate a typical elementary classroom. Additionally, to increase the stimulation of the setting, students were asked to sit at a school table facing a window. There was intermittent movement of teachers in and out of the room throughout each session, as is typical in some classrooms.

For each 20-min session, a CD player was placed in front of the student and a recording was played. Students were to listen to the problem and give a verbal answer. Participants were presented with the math problems in two counterbalanced conditions, with and without the fine motor activity.

Prior to baseline, participants were given two practice trials with similar math problems to become familiar with the recording and the 20-second pause. During baseline and intervention, participants were instructed to listen to the math problems and give a verbal response as soon as possible. Whether or not the student responded, the recording moved to the next problem after the 20-second pause. The researcher sat 10 feet behind the participant and recorded his or her verbal responses. All sessions were videotaped to verify students' verbal responses to the math questions.

During intervention, procedures were the same as in baseline, except students were provided with the fine motor activity, a Tangle Puzzle-Jr., a plastic circle-

shaped toy with a series of 90-degree curves, connected and able to pivot at each joint. The Tangle Puzzle-Jr. was chosen for the fine motor activity because it was flexible, easy to manipulate, twist and swivel and was not noisy. Additional description and a photo of the Tangle Puzzle-Jr., is available at <http://www.tangletoys.com/>. Participants were instructed to use the Tangle toy to help them concentrate. The number of problems answered correctly was recorded and graphed.

Results

Accuracy data for the three participants are presented in Figures 1–3. All three participants answered the greatest number of problems correct in sessions when they were using the tactile object. Julian and Tom showed clearly improved performances in sessions with the fine motor activity.

Study 2

Participants and setting

Three 10-year-old, English-speaking students attending a general education fifth grade classroom in a suburban elementary school in the USA were invited to participate in this study. All three had been diagnosed with ADHD and were on stimulant medication. Participants are referred to by the pseudonyms Pete, Rett and Amy. Their inattention and hyperactivity status was confirmed with Parent and Teacher ratings on the Conner’s Rating Scales (Conners, 1997). All three students had *t*-scores of 60 or higher (1 or more SD above the mean) on either the (1) Cognitive/Inattention Index, (2) Hyperkinesis Index or (3) the ADHD Index on either the parent or the teacher ratings. See Table 2 for scores.

Procedures

Math word problems were selected from fifth grade math text books. Each problem required two operations and each was equivalent in reading level and the number of words. A PowerPoint slide was created for each problem and was timed to be

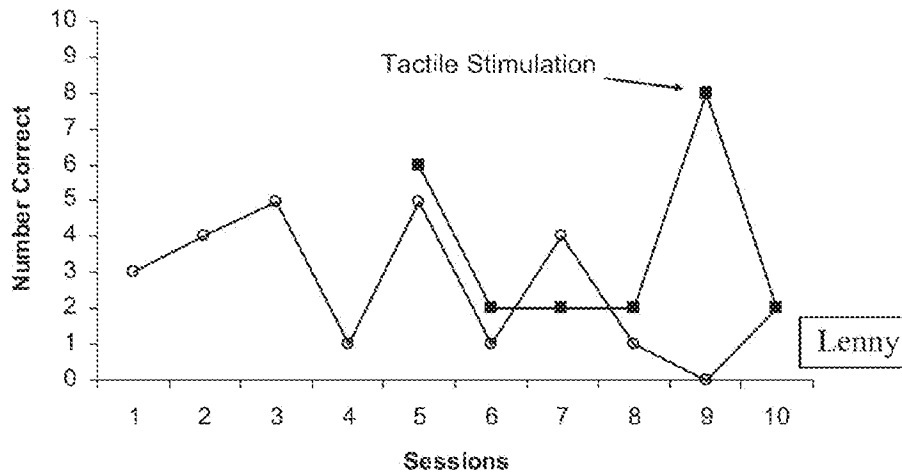


Figure 1. Number of math problems correct for Lenny with and without tactile stimulation.

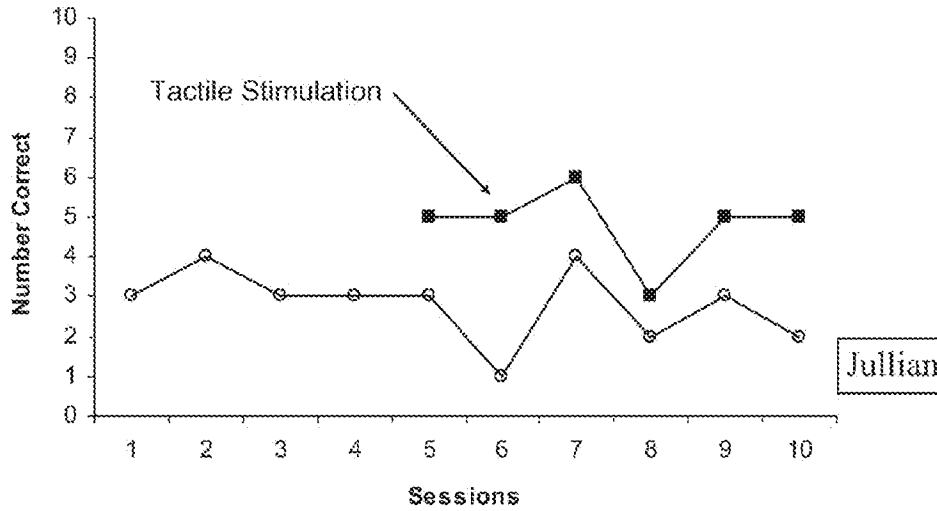


Figure 2. Number of math problems correct for Julian with and without tactile stimulation.

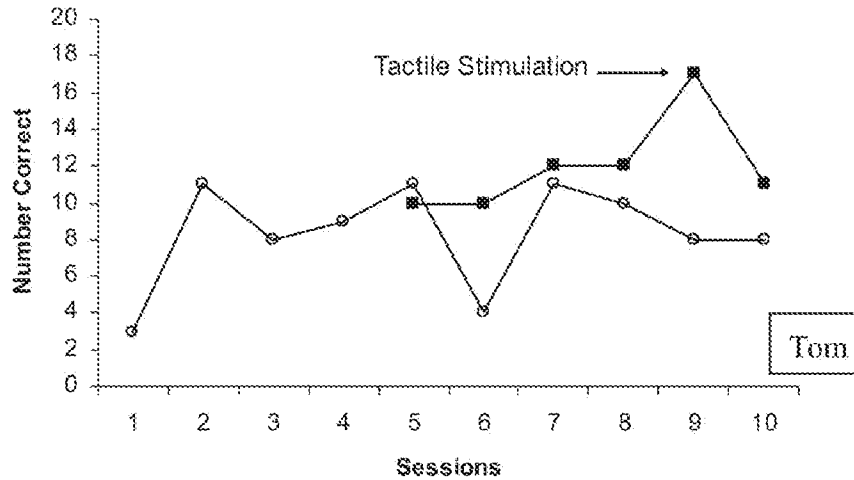


Figure 3. Number of math problems correct for Tom with and without tactile stimulation.

Table 2. Scores on the Conner's Rating Scale, Study 2.

	Teacher ratings			Parent ratings		
	Pete	Rett	Amy	Pete	Rett	Amy
Cognitive/Problems/Inattention	76	51	75	*	74	88
Hyperactivity	82	43	58	*	72	79
Conners ADHD Index	83	44	66	*	79	90
Conners Global Restless Impulsive	83	43	62	*	77	90
Conners Global Index: Total	80	43	68	*	81	90
DSM-IV Inattentive	77	53	81	*	79	90
DSM-Hyperactive Impulsive	83	44	45	*	85	80
DSM-IV: Total	90	48	66	*	84	90

Note: Scores are *t*-scores with a mean of 50 and standard deviation of 10; *scores were unavailable; rating scales were not returned.

projected for 40 seconds then automatically transition to the next problem. Students were asked to give verbal answers to the problems before the next problem appeared on the screen.

Sessions were conducted with each student individually between 10 and 11:00 am in a conference room in the participants' elementary school. There were no interruptions or windows in this room but the room was decorated with posters. Twenty-five word problems were presented in each session.

Each participant was assessed 20 times, 5 consecutive times in each of 4 conditions: (1) baseline, (2) distraction, (3) distraction plus fine motor activity and (4) fine motor activity. In the baseline condition, slides were viewed without distraction and without the fine motor activity. In the distraction condition, distraction was added during the task by playing an audio recording of children talking, music, TV sounds, a pencil being sharpened and a telephone ringing. Distracting noises occurred randomly at a rate of approximately once every four minutes and lasted between 30 seconds and 2 minutes. The same sounds were used for each session but the sequence varied. The tape player was placed two feet behind the participant who was seated at a table facing a laptop computer screen.

In the Fine Motor condition students were provided a Tangle Puzzle-Jr. toy, as in Study 1, and were told to use it to help them concentrate. In the Distraction Plus Fine Motor Activity condition, both the distractions and fine motor activity were presented. Conditions were presented in counted-balanced order to control for order effects. The sequence of sessions is presented in Table 3. As in the first study, the researcher sat behind the student and recorded their verbal answers to the math problems. Sessions were again video taped to verify responses.

Results

Results are presented in Figures 4–6. Results for Pete and Rett show that when distraction was introduced, there was a negative effect on performance. When the fine motor activity was available along with distraction, their performances were similar to baseline. Results for Amy are less clear. In the Fine Motor Only condition, Rett and Amy performed similar to their baseline performances. Pete's performance in this condition was highly variable and may have declined.

Discussion

The purpose of these studies was to assess the effects of the use of a fine motor activity on the math problem solving of students with ADHD in an analog classroom setting that simulated the distractions and stimulation found in a typical elementary classroom. In the second study, auditory distractions were added to

Table 3. Order of experimental conditions.

Week (5 days)	Rett	Pete	Amy
1	Fine motor only	Baseline	Distraction + fine motor
2	Distraction	Distraction + fine motor	Fine motor only
3	Baseline	Fine motor only	Distraction
4	Distraction + fine motor	Distraction	Baseline

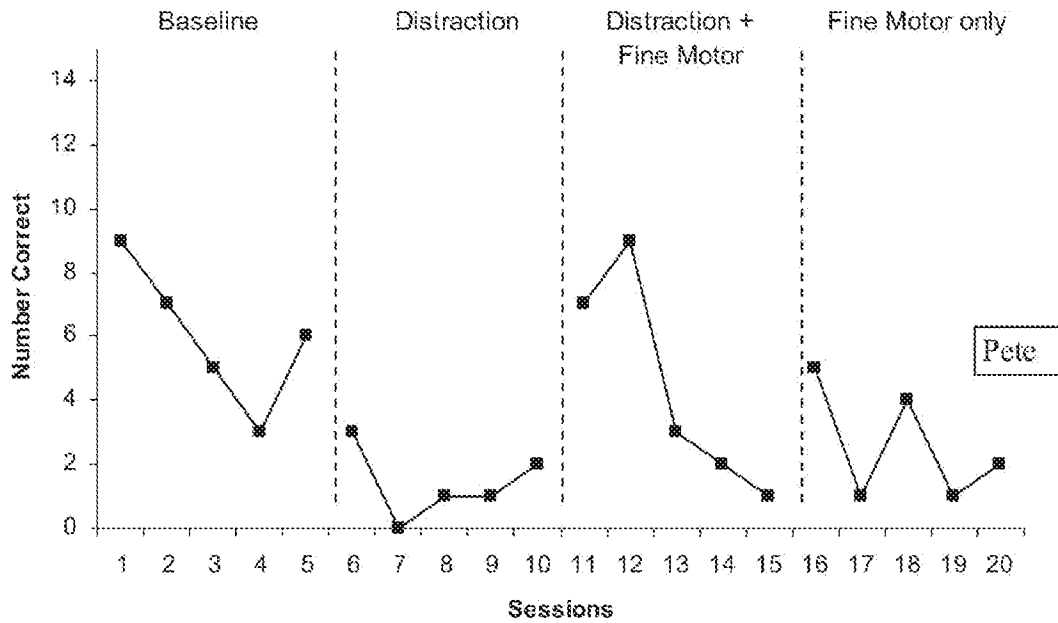


Figure 4. Number of problems correct for Pete in distraction and no distraction condition, with and without tactile stimulation.

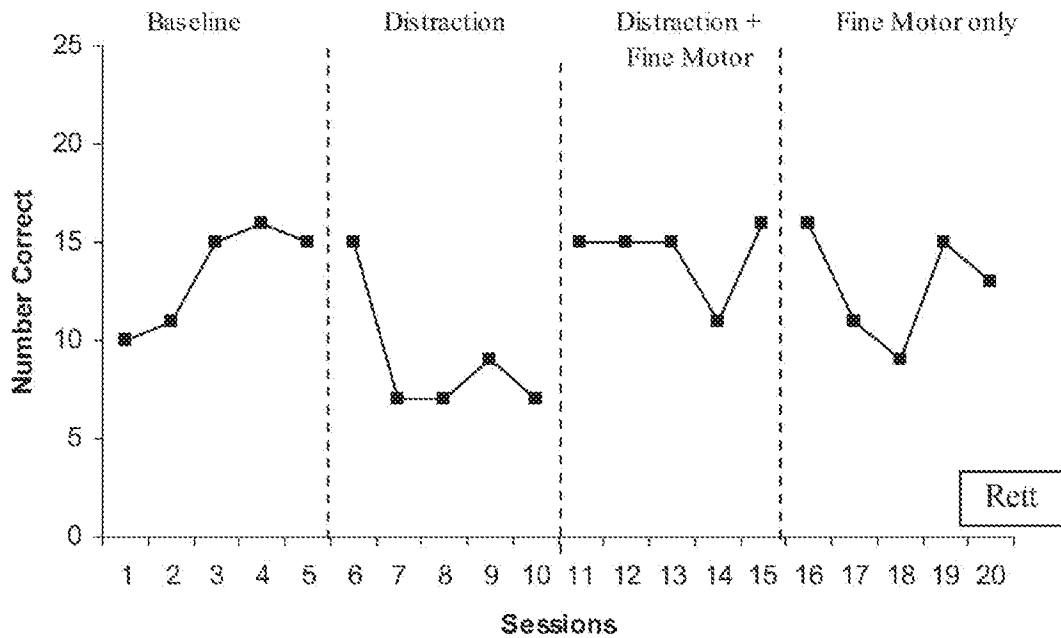


Figure 5. Number of problems correct for Rett in distraction and no distraction condition, with and without tactile stimulation.

determine if the fine-motor activity could help students with ADHD reorient to their tasks after distraction. We anticipated that students would concentrate more on their tasks when using the fine motor activity and would be able to resist attending to distractions or re-orient after distracted. We drew insight for this intervention from the informal observation of student-selected behavior during concentration. Theoretically, the fine motor activity provided stimulation and regulation that would allow students to focus on the task until problems could be solved.

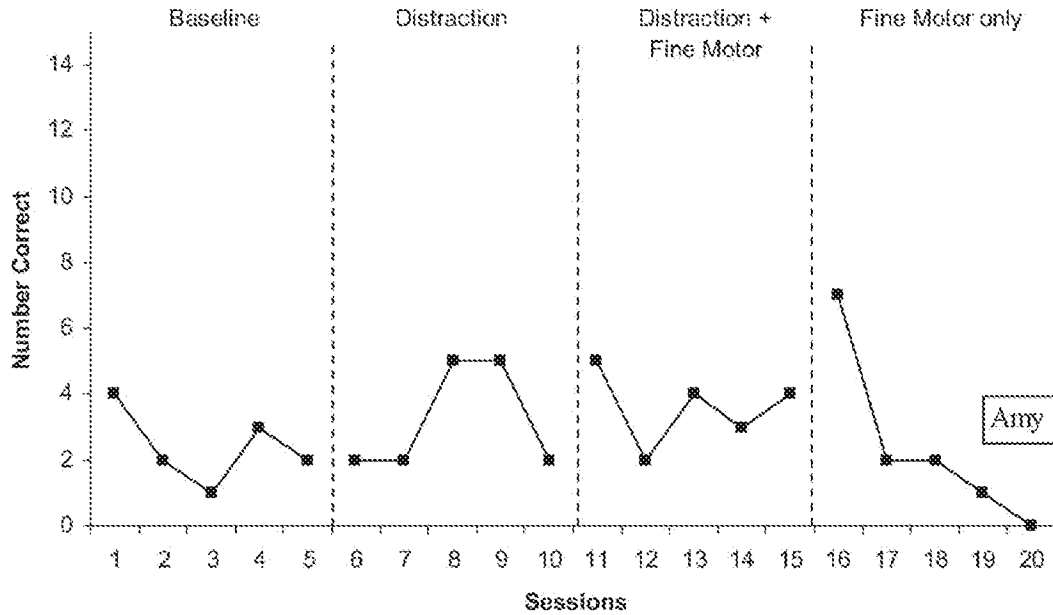


Figure 6. Number of problems correct for Amy in distraction and no distraction condition, with and without tactile stimulation.

The results of this study should be considered along with its limitations. All participants in this school-based study had been diagnosed with ADHD but these diagnoses were not confirmed for this research with clinical evaluations. This may be viewed as both a strength and a limitation. As a limitation, participants may have been misdiagnosed. As a strength, these participants represent the level of ADHD symptomology found in typical classrooms. A more severe clinical population may show different results. A second limitation of this study was the presentation of tasks. In the first study, the task was presented verbally whereas in the second study it was presented visually, limiting the comparison of the results of the two studies.

Results from Study 1 showed that all three students performed better when the fine motor activity intervention was available. These results support and extend those presented by Kercood et al. (2007), who found the same fine motor activity (i.e. the Tangle toy) facilitated math problem solving in a non-analog classroom setting and with a written task response. In the present study, the classroom environment was analogous to a typical classroom in type of stimulation and distraction. It was not analogous in that other students were not present, a limitation. For a next step, future researchers will want to assess the effects of fine motor activity during problem solving in a typical classroom with other students present. In the present study, a written response was not in competition with the use of the fine motor activity and results were clearly demonstrated.

In Study 2, we assessed the effects of fine motor activity on the math problem solving of students with ADHD when auditory distractions were presented. Zentall and Shaw (1980) reported that students are most distracted by conversation in the classroom. Distractions in Study 2 included conversation, a telephone ringing and other highly distracting sounds that lasted up to two minutes. Results showed that when the fine motor activity was available, two of the three students were able to

respond to the task at levels equal to the Baseline condition (no distraction). Although these results are for only two participants, it lends support to the idea that engaging in a fine motor activity may assist students with ADHD in resisting the pull of distraction or in reorienting their thoughts quickly after attending to distraction. Students were able to sustain their attention to the task well enough to answer more math story problems correctly when using the fine motor activity.

Interpreting the results of the Fine Motor Only condition is more complex. Results are not directly comparable to those from the first study or those presented by Kercood et al. (2007) because of differences in the presentation of the problems and modalities of response. In the first study, problems were presented on auditory tape instead of on a computer screen. It may be that fine motor activity is useful for tasks that require listening but are less useful for tasks that require reading. Reading may provide adequate stimulation so that a fine motor activity does not facilitate concentration and may even be a distraction. Additionally, tasks that require a written response may be less affected by the tactile stimulation provided by the fine motor activity.

Future research is clearly needed to clarify the effects of fine motor activity on the task performances of students with ADHD. An advantage of a fine motor activity is that it is small, portable, silent, private and student directed. When students learn how to use the activity, they can select when and where to use it to facilitate their concentration and problem solving. More research is needed to clarify under what conditions the use of a fine motor activity is facilitative and when it may be disruptive. In the present studies, students were required to respond within a short period of time. Future researchers may want to compare the effects of a fine motor activity with timed and un-timed responses. Additionally, Botvinick and Bylsma (2005) found that distraction at a decision point of a task is more disruptive than at other points of a task. Future researchers who assess the effects of distraction may want to consider when the distraction occurs.

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