The Effects of Auditory Stimulation on the Arithmetic Performance of Children with ADHD and Nondisabled Children

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Abstract

This study evaluated the impact of extra-task stimulation on the academic task performance of children with attention-deficit/hyperactivity disorder (ADHD). Twenty boys with ADHD and 20 nondisabled boys worked on an arithmetic task during high stimulation (music), low stimulation (speech), and no stimulation (silence). The music "distractors" were individualized for each child, and the arithmetic problems were at each child's ability level. A significant Group × Condition interaction was found for number of correct answers. Specifically, the nondisabled youngsters performed similarly under all three auditory conditions. In contrast, the children with ADHD did significantly better under the music condition than speech or silence conditions. However, a significant Group × Order interaction indicated that arithmetic performance was enhanced only for those children with ADHD who received music as the first condition. The facilitative effects of salient auditory stimulation on the arithmetic performance of the children with ADHD provide some support for the underarousal/optimal stimulation theory of ADHD.

Clinically, we find that parents of children with attention-deficit/hyperactivity disorder (ADHD) often report that their children insist on doing homework while the radio or TV is playing, and they worry that this backdrop distracts their children and interferes with academic performance. It has also been reported in the literature that undiagnosed elementary-school children tend to study in the presence of "distractors" (Patton, Routh, & Stinard, 1986; Patton, Stinard, & Routh, 1983). Moreover, Patton et al. (1986) found that children's selection of background stimulation was influenced by the type of homework task. The authors suggested that the extra-task stimulation preferred by children for certain assignments (e.g., stereo music or TV while working on mathematics) "may be beneficial because it helps the student avoid boredom and therefore stay 'on task' for a longer time" (p. 440). The face validity of this suggestion notwithstanding, there is little information regarding the impact of such background stimulation on the academic performance of children, especially children with ADHD.

Studies addressing this issue have potentially both practical and theoretical value and could help to elucidate the nature and function of distractibility in children with ADHD. Specifically, although the attentional difficulties of children with ADHD have been well documented (e.g., Barkley, 1990; Douglas, 1983; Goldstein & Goldstein, 1990; Schachar, 1991), an issue that remains unsettled is whether the associated symptom of distractibility is functionally impairing in these youngsters. It is particularly unclear whether, and under what conditions, children with ADHD are distractible and consequently more susceptible to the interfering effects of extraneous stimuli (e.g., Ceci & Tishman, 1984; Prior, Sanson, Freethy, & Geffen, 1985; Radosh & Gittelman, 1981; Rosenthal & Allen, 1978, 1980; Zentall, Zentall, & Booth, 1978). Among the various theoretical models of the supposed deficit underlying ADHD (Barkley, 1994; Douglas, 1983; Douglas & Parry, 1983; Voeller, 1991; Zentall, 1975; see Hinshaw, 1994, for a review), the underarousal/optimal stimulation theory proposed by Zentall seems to most directly address the issue of distractibility (see Zentall, 1975, 1993; Zentall & Zentall, 1983). In so doing, it provides a potential explanation for why children with ADHD are reported to prefer doing homework with background stimulation, as well as an explanation for inconsistent research findings regarding the impact of distractors on these youngsters' performance.

According to the underarousal/optimal stimulation theory, the distractibility of children with ADHD is a functional attempt by the youngsters to modulate their underarousal by seeking increased levels of stimula-

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tion or novelty. It is postulated that in certain situations—particularly during monotonous, routine tasks that are well learned—the performance of children with ADHD, rather than deteriorating, will benefit from increases in self-induced or external stimulation, both of which presumably increase arousal to an optimal level (Zentall & Zentall, 1983). Relatedly, Kinsbourne (1983) suggested that unless a task is highly stimulating, that is, has sufficient subjective salience for youngsters with ADHD, the children will periodically drift off task, presumably seeking stimulation in the off-task environment. When highly salient sources of stimulation are available, focused and effortful behavior becomes more possible. Other recent proponents of the optimal stimulation theory include Van der Meere, Vreeling, and Sergeant (1992) and Leung and Connolly (1994).

Several laboratory studies provide support for the facilitative effects of salient, or stimulating, distractors on the performance of children with ADHD. For example, Kinsbourne and colleagues found that a variety of stimulating conditions (e.g., increased rate of stimulus presentation, white noise) enhanced children's performance on paired-associate learning tasks (Conte & Kinsbourne, 1988; Conte, Kinsbourne, Swanson, Zirk, & Samuels, 1986; Kinsbourne, 1992). Zentall and Kruczek (1988) reported that, relative to nondisabled controls, teacher-identified children with hyperactivity improved on a letter-copying task when task stimulation was increased via the addition of colored stimuli.

Relatively few investigations have been undertaken on the facilitative effect of increased stimulation on the performance of children with ADHD on more ecologically valid tasks. The studies that do exist have evaluated the impact of extra-task distractors on academic performance. One study (Radosh & Gittelman, 1981) found that children with ADHD were negatively affected by external stimulation when the academic task was difficult. Compared to nondisabled children, youngsters with hyperactivity made significantly more errors on a relatively demanding arithmetic task under conditions of both high- and low-appeal distraction.

Other studies using ecologically valid tasks, however, indicate that the task performance of children with ADHD is not impaired, and may even be facilitated, by external distractors. For example, Bremer and Stern (1976) reported that although the children with hyperactivity attended more than the nondisabled children to auditory distractors during a reading task, no significant differences in reading performance were found between the groups during the distraction condition. Zentall and Zentall (1976) found that on an "academically related performance task" (p. 694), a high-stimulation condition consisting of auditory and visual distractors did not impair task performance. The facilitative effects of high extra-task stimulation on academic performance was suggested by Scott (1970), who reported improved classroom math productivity in 4 hyperactive children during the playing of background rock and roll music, compared to their productivity under normal classroom stimulation. However, the small sample size and lack of a control group precluded any meaningful data analysis. More recently, Pelham et al. (1994) reported that among 41 elementary-school–age children with ADHD attending a summer treatment program, approximately 30% demonstrated significant increases in completion rates of assigned academic seatwork when rock music was playing in the classroom. In contrast, none of the 26 nondisabled comparison children increased their academic productivity when music was playing.

In summary, research evidence pertaining to the effects of "real-life" extra-task distractors on ecologically valid tasks is not clear-cut. Although empirical evidence tends to support the premise that external distractors may not hinder, and may even facilitate, academic performance under certain conditions, the task factors and characteristics of the distractors, especially issues of salience, need to be systematically investigated.

The aim of the current study was to evaluate the impact of commonly occurring forms of extra-task stimulation on the academic task performance of youngsters with ADHD and nondisabled children. To this end, we examined the effects of auditory distractors on the arithmetic performance of the two groups. Specifically, arithmetic performance was assessed under three background conditions reflecting different levels of salience: music, speech, and silence. To increase the contrast of salience, the musical distractors were chosen on the basis of their individual appeal for each subject. In addition, task factors met critical parameters of the optimal stimulation theory in that the math problems were routine and geared to the ability level of each individual, so that they posed no unusual challenges.

Method

Participants

During recruitment, participants were told that this project was examining the conditions under which children typically complete their homework. The common dispute between parents and children about whether the radio or TV should be playing during homework periods was an area of special interest. The children were also told that they would be doing school-related tasks under a variety of auditory-background conditions, one of which would be the presence of their favorite music.

The study participants consisted of two groups of boys in Grades 2 through 6: an outpatient clinic sample of children with ADHD, and nondisabled controls.

ADHD Criteria. To receive an ADHD diagnosis, the youngsters had to meet DSM-III-R (American Psychiatric Association, 1987) criteria for the disorder, established via the parent version of the Diagnostic Interview for Children and Adolescents (DICA-P; Herjanic & Campbell, 1977). The interview schedule was modified slightly to reflect DSM-III-R criteria for the Disruptive Behavior Disorders. In addition, to be considered for the study, the children had to receive a score of at least 1.5 out of a possible 3.0 on the Hyperactivity factor of the Conners Teacher Rating Scale (CTRS; Goyette, Conners, & Ulrich, 1978). Further, children needed a scale score of at least 8 on the Wechsler Intelligence Scale for Children–Revised (WISC-R; Wechsler, 1974) Vocabulary subtest. Youngsters were excluded if they were psychotic or had a concomitant diagnosis of Major Affective Disorder, Separation Anxiety Disorder, Pervasive Developmental Disorder, or Developmental Arithmetic Disorder. Specifically, children were excluded if they had a standard score on the Arithmetic subtest of the Wide Range Achievement Test–Revised (WRAT-R; Jastak & Wilkinson, 1984) of 85 or less (i.e., 1 *SD* below the mean) *and* a standard WRAT-R Arithmetic score 15 or more points below their estimated intellectual ability, based on their WISC-R Vocabulary score. Finally, children were not included in the study if their functional score on Arithmetic Screening Test (AST) (see below) was lower than second grade.

Children receiving psychostimulant medication had to be medication free for at least 24 hours prior to testing. The CTRS scores reflect the youngsters' school behavior off medication.

Nondisabled Controls. The control children were recruited from local school districts and were matched for grade with the youngsters with ADHD. To be considered, they had to be in general education classes, have no history of psychiatric treatment, and have a WISC-R Vocabulary scaled score of at least 8. They were excluded if their CTRS Hyperactivity factor score was 1.5 or greater and if they received a teacher rating of at least 2 ("pretty much") on a 4-point global behavior-problem rating scale. In addition, they were not considered for the study if their WRAT-R and estimated intellectual ability scores indicated a Developmental Arithmetic Disorder, or if their AST functional score was less than second grade.

Study Sample. Forty boys entered the study, 20 with ADHD and 20 without. Nine of the children with ADHD were Caucasian, 8 African American, and 3 Hispanic. In the nondisabled group, 14 youngsters were Caucasian, 4 were African American, and 2 were Asian. Twelve (60%) of the children with ADHD were in special education classes. Six youngsters with ADHD were receiving psychostimulant medication (Ritalin), with a mean daily dose of 17.5 mg/d (range = 5 to 45 mg/d). A number of the children with ADHD had a concurrent diagnosis: Four had a diagnosis of Conduct Disorder, 9 had an Oppositional Defiant Disorder (ODD) diagnosis, 7 had a Specific Developmental Disorder (SDD) other than in arithmetic, and 4 were comorbid for both ODD and SDD.

Table 1 depicts demographic and other group characteristics. As can be seen, no significant group differences in age were found (mean = 9.9 yrs, range = 7.5 to 13 yrs). As expected, the mean CTRS Hyperactivity score of the ADHD group ($M = 2.38$, $SD = .40$) was significantly higher than that of the control group ($M = .35$, $SD = .41$), $t(38) = 15.80$, $p < .001$). In addition, the youngsters with ADHD were significantly lower than the controls in estimated intellectual ability, $t(38) = 4.35$, $p < .001$; WRAT-R Arithmetic score, $t(38) = 4.06$, $p < .001$; and SES (Hollingshead & Redlich, 1958), $t(38) = 4.09$, $p < .001$.

Procedure

Each child participated in the study over 2 days. The parents were paid $30 at the completion of the study. During the first day, the WRAT-R Arithmetic subtest, the WISC-R Vocabulary subtest, and the Arithmetic Screening Test (AST) were administered. The children were asked to provide the titles of their favorite songs, as well as the names of the artists who performed them.

The AST was adapted from the arithmetic material developed by Douglas, Barr, O'Neill, and Britton (1986). There were five AST levels, corresponding to grade levels 2 through 6. Each AST consisted of 10 arithmetic problems. Exams on levels 2, 3, and 4 contained addition and subtraction problems only; exams on levels 5 and 6 also included multiplication problems. The order of the mathematical problems was randomized, and the problems were computer generated.

Each youngster was given the AST that was one grade level below his grade-level arithmetic score on the

TABLE 1
Sample Characteristics

	ADHD		Nondisabled		
	M	*SD*	*M*	*SD*	*p*
Age	10.08	1.51	9.78	1.16	ns
SES	3.45	1.00	2.25	.85	.000
CTRS[a]	2.38	.40	.35	.41	.000
WISC-R Vocabulary[b]	9.55	2.04	12.95	2.84	.000
WRAT-R Arithmetic	95.90	8.83	110.50	13.45	.000

Note. $n = 20$ in each group. ADHD = attention-deficit/hyperactivity disorder; WISC-R = Wechsler Intelligence Scale for Children–Revised; WRAT-R = Wide Range Achievement Test–Revised.
[a]Conners Teacher Rating Scale Hyperactivity Factor. [b]Scaled scores.

WRAT-R. The AST was not timed. If the child's AST score was 80% or higher (i.e., 8 out of 10 correct), he was given the next higher AST level. A child's functional grade level was defined as the highest level at which he obtained a score of at least 80%. If a youngster's score was below 80% on the first AST administered, he was given the AST at the next lower level, and this process continued until he achieved a score of at least 80%.

Prior to the second test session, a 10-minute audiotape was prepared consisting of each subject's favorite music. Whenever possible, a child's three favorite songs were edited onto a tape, using an A–B–C song sequence. In cases where only two songs were named or a song could not be obtained, the edited tapes consisted of two songs, alternating over the 10-minute period.

On the second day of testing, the children were administered three arithmetic exams at the grade level corresponding to their functional performance on the AST. Thus, despite differences in the actual math problems completed, the caliber of challenge faced by each child was held constant. The exams were taken from Douglas et al. (1986) and consisted of three equivalent forms at each grade level. The forms contained 60 problems printed on two pages. The pages were arranged in five horizontal rows of six problems each. The arithmetic operations on the exams were the same as those on the AST of the same grade level.

The arithmetic exams were administered under three experimental conditions: (a) 10 minutes of music, (b) 10 minutes of background speech, and (c) 10 minutes of silence. The participants with ADHD were randomly assigned to one of six groups, each of which received a different sequence of conditions, that is, music–speech–silence, music–silence–speech, speech–music–silence, speech–silence–music, silence–music–speech, or silence–speech–music. Each nondisabled control child was yoked to a child with ADHD according to grade and received the same sequence of experimental conditions given to his ADHD counterpart. There were five-minute breaks between testings, during which the child waited outside the testing room. The speech condition consisted of a 10-minute audiotape of a nightly business report aired on local television. There was no music during the broadcast, and no commercial interruption; the recording contained business news only.

The children sat at a desk during testing. A Panasonic radio/dual cassette recorder with speakers attached was placed approximately 3 feet in front of the children. The dials on the front of the unit were covered with a piece of cardboard to minimize visual distraction and to prevent participants from tampering with the unit during testing. The experimenter sat at a desk in the back of the room, approximately 8 feet behind the children. The children were told that the experimenter would be completing paperwork while they worked on the arithmetic tasks. The music and speech tapes were played at a volume of 70 decibels, as determined by a sound-level meter placed 3 feet in front of the sound source.

Results

Arithmetic Performance

Three scores were generated for each subject: the number of math examples attempted, the number of correct answers, and an accuracy score (i.e., the number of examples answered correctly divided by the number attempted). Although the groups differed significantly in estimated intellectual ability and SES, correlations between these measures and scores on the arithmetic exams were all low and nonsignificant, indicating that covariance procedures were unnecessary and corroborating that the arithmetic exams, which were given at each child's functional level, controlled for individual differences in arithmetic ability. Accordingly, each of the three dependent measures was analyzed using a 2 (Group: ADHD, Nondisabled) by 3 (Auditory Condition: Silence, Speech, Music) repeated-measures analysis of variance.

Table 2 presents the number of problems attempted, number of correct answers, and accuracy scores for the children with ADHD and nondisabled children under the three auditory conditions.

Number of Problems Attempted. The groups did not differ significantly in the number of arithmetic problems they attempted, $F(1, 38) = .01$. In addition, no main effect for the auditory conditions, $F(2, 76) = .47$, was found, nor was there a significant Group × Condition interaction, $F(2, 76) = 1.81$.

Number of Correct Answers. With regard to the number of correct answers, there was no significant main effect for group, $F(1, 34) = .14$, or condition, $F(2, 68) = 1.23$. However, there was a significant Group × Condition interaction, $F(2, 68) = 5.94$, $p < .004$. A follow-up analysis of simple main effects (Winer, 1971) for the ADHD group was significant, $F(2, 76) = 5.36$, $p < .01$. Newman-Keuls post hoc tests indicated that under the music condition, the children with ADHD had more correct answers than during the speech ($p < .01$) or silence ($p < .05$) conditions. No difference was found in the performance of the children with ADHD between the speech and silence conditions. The simple main effects analysis for the nondisabled group was nonsignificant, indicating that the nondisabled youngsters performed similarly under the three background conditions. Finally, the simple main effects analyses comparing the ADHD and nondisabled youngsters under each of the three distraction conditions yielded no significant differences.

Accuracy. The groups did not differ significantly in their overall accuracy scores, $F(1, 26) = .03$, nor was

TABLE 2
Mean Arithmetic Performance Under Different Auditory Conditions

Group	Condition		
	Music	Speech	Silence
ADHD			
Correct	26.1 (15.9)	19.4 (13.8)	21.0 (15.1)
Attempts	30.1 (15.8)	25.7 (16.6)	28.0 (16.9)
Accuracy	.83 (.12)	.77 (.24)	.79 (.22)
Nondisabled			
Correct	22.0 (8.4)	24.2 (8.5)	24.2 (11.2)
Attempts	26.6 (9.3)	28.0 (9.7)	28.0 (11.9)
Accuracy	.82 (.14)	.86 (.09)	.86 (.09)

Note. Numbers in parentheses are standard deviations. ADHD = attention-deficit/hyperactivity disorder.

there a significant main effect for conditions, $F(2, 52) = .30$, or for the interaction of Group × Condition, $F(2, 52) = 1.62$.

Order Effects. Inspection of the groups' performance, based on the order in which the three auditory conditions were presented, indicated that the children with ADHD who had music presented as the first condition had more than twice as many correct answers as the youngsters with ADHD who received music as the second or third condition (see Figure 1). To follow up on this observation, analyses were conducted to examine the effects of order of presentation of music on arithmetic performance. A 2 (Group: ADHD, Nondisabled) × 3 (Order: first, second, third) ANOVA on number of correct answers indicated a significant order effect, $F(2, 34) = 5.03$, $p < .02$, which needed to be interpreted within the context of a significant Group × Order interaction, $F(2, 34) = 4.77$, $p < .02$. To decompose this interaction, a posteriori Newman-Keuls tests were performed. The results indicated that the children with ADHD who received music as the first condition had significantly more correct answers than did children with ADHD who received music in the second or third order, and significantly more correct answers than the nondisabled children regardless of the order in which they received music ($ps < .05$). All other multiple comparisons were nonsignificant.

We considered the possibility that the significant Group × Order interaction was attributable to differences between the children with ADHD who received music first and those who received it in the second or third order. However, analyses indicated that these youngsters did not differ significantly in age, SES, race, estimated intellectual ability, CTRS Hyperactivity scores, grade level, or special education status (i.e., placement in a mainstreamed or special education classroom). Furthermore, no differences existed between the children with ADHD who received music first and the other youngsters with ADHD in academic skills as measured by the WRAT-R Arithmetic scores, or in functional arithmetic level as determined by the AST. The type of music chosen by the children for the experiment also did not distinguish the groups. Similarly, the nondisabled children who received music in one of the three serial music positions did not differ significantly from each other on these measures.

ANOVAs were also conducted to examine the Group × Order interactions for accuracy and number of problems attempted under the music condition. The interaction effect was not significant for accuracy, $F(2, 34) = .26$, but was significant for number of attempts, $F(2, 34) = 5.36$, $p < .01$. Newman-Keuls tests indicated that the children with ADHD who received music first attempted significantly more problems ($M = 42.29$, $SD = 18.22$) than the children with ADHD who received music in the second order ($M = 23.50$, $SD = 11.26$) or third order ($M = 23.57$, $SD = 11.26$), and significantly more than did the nondisabled youngsters who received music in the first order ($M = 24.14$, $SD = 8.05$) or second order ($M = 21.67$, $SD = 9.18$) ($ps < .05$), but not the third order ($M = 33.14$, $SD = 12.93$).

In light of these Group by Order effects for music, ANOVAs were similarly carried out to examine whether there were differential order effects on arithmetic performance in the speech and silence conditions. For neither condition were the Group × Order interactions significant for number of correct answers, accuracy, or number of problems attempted.

Discussion

The results help to shed some light on the impact of auditory distractors on the arithmetic performance of children with ADHD. Overall, auditory stimulation did not adversely affect the performance of either the children with ADHD or the nondisabled youngsters. Moreover, the arithmetic performance of the youngsters with ADHD actually benefited from music, whereas the nondisabled children performed similarly under the three auditory conditions. When music was playing, the children with ADHD increased their number of correct answers by 33% and 23% relative to their performance during speech and silence, respectively. In comparison, the nondisabled children averaged 9% fewer correct answers when exposed to music than when working under silence or background speech—a nonsignificant difference.

We considered the possibility that the group differences obtained during the music condition might be attributable to differences in the type of music selected by the children. Perhaps children with ADHD preferred music with a faster beat than that chosen by nondisabled youngsters. If

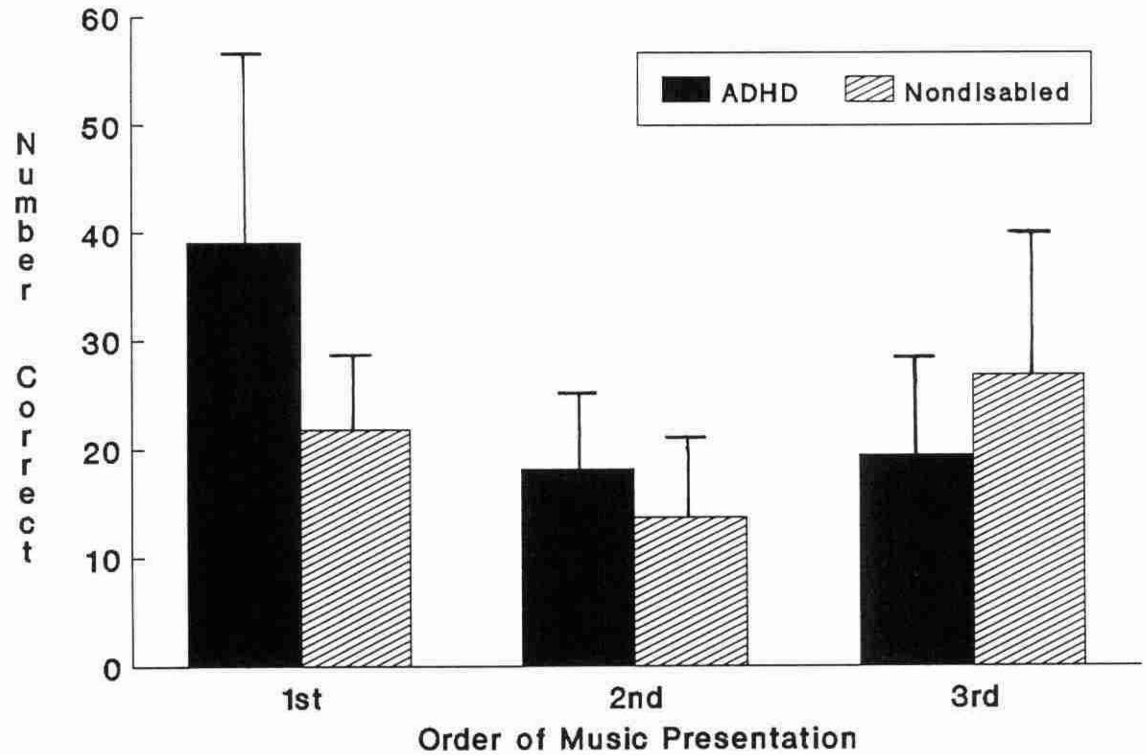

FIGURE 1. Number of correct answers based on order of presentation of music condition.

so, then it could be posited that the results were a function of group differences in the intensity of background stimulation. However, 98% of all the children selected rock and roll or rap music. When music preference was analyzed in greater detail, no differences were found in the type of musical selections between the ADHD and nondisabled comparison groups, between groups according to the order in which the background stimuli was presented, or between children with ADHD who did best during music versus their counterparts who did best during nonmusic conditions. Thus, the benefits associated with music in the group with ADHD appear to be related to the facilitative effects of appealing, highly salient stimulation for these youngsters.

Furthermore, the level of appeal, rather than the mere presence of stimulation, appears to be the critical influential feature for children with ADHD, as performance during the background speech condition was not different from performance during silence for either group. Perhaps background speech consisting of more interesting or relevant content for the youngsters, rather than a business news broadcast, would have had a different effect on the children's performance.

Notably, an unanticipated serial order effect indicated that music's facilitative effects were contingent upon when the music was presented. The significant increase in number of arithmetic problems attempted and in number of correct answers resulted only when music occurred during the first 10-minute block and not if it occurred during the subsequent 10-minute blocks.

There is no ready explanation as to why enhanced performance occurred only when music was introduced first. The simplest explanation would be that those youngsters with ADHD who received music first were different from the other participants with ADHD on some critical characteristic that was not controlled by design. However, because no difference between ADHD groups was found in demographic characteristics, in measures of academic functioning, or in the type of music they selected, it is difficult to imagine what such a characteristic would be. Moreover, because the performances of the ADHD groups did not differ under the two nonmusic conditions, it is highly unlikely that the improved arithmetic performance of the group that received music first was due to a unique characteristic that became apparent only under specific conditions.

Alternatively, consideration needs to be given to the possibility that music's initial facilitative effects could not counteract boredom. Douglas and Peters (1979) have noted that children with ADHD bore easily and have difficulty sustaining attention when they are required to repeat a task. However, empirical support for such a deficit in sustained attention — a postulated hallmark of ADHD (Douglas, 1983) — has been equivocal. Compared to nondisabled controls, children with ADHD have shown differential performance decrements over time in some studies (Pelham, Schneider, Carlson, & Evans, 1992; Peters, cited in Douglas, 1983; Seidel & Joschko, 1990) but not in others (Kupietz, 1990; Prior et al., 1985; Schachar, Logan, Wachsmuth, & Chajczyk, 1988; Van der Meere & Sergeant, 1988; Van der Meere, Wekking, & Sergeant, 1991).

A partial explanation of our findings is provided by the underarousal/optimal stimulation theory, which predicts that music will facilitate performance but does not necessarily predict the serial order effects obtained. Specifically, the theory posits that on routine tasks that are not especially difficult and do not require new learning, salient stimulation can increase arousal to more normal levels in youngsters with ADHD, thereby improving performance. Although, as described earlier, there are reports that provide empirical support for this notion, most studies have not assessed changes in performance as a function of when stimulation is introduced. Notably, studies that have examined the effects of timing typically have used *within-task* stimulation designs. In these cases (e.g., manipulations of letter color and size in spelling tasks; Zentall et al., 1978), enhanced performance occurs when the within-task stimulation occurs *later* rather than earlier in the trial.

In contrast to within-task designs, in the *extra-task* stimulation design used in the present study, the facilitative effect of the highly salient distractor occurred only when it was introduced at the *onset* of the experimental situation. This suggests that in children with ADHD, at least with regard to arithmetic performance, there is a limited window of opportunity for the augmenting effects of an extra-task salient distractor. However, to fully address this hypothesis would require that the children's performance be repeatedly sampled under fixed stimulus conditions over an extended time period. A study in which the performance of children with ADHD and nondisabled children was compared under sustained high-arousal conditions, such as music, and under sustained conditions that were less stimulating, could help to ascertain whether music's initial positive effects would be maintained, or would at least retard a dropoff in performance, if the same music was present throughout the task.

Similarly, it would be useful to determine whether the arousal effects of appealing stimulation can be maintained via the introduction of novelty. This possibility stems from Kinsbourne's (1992) suggestion that deployment of effort is contingent upon sufficient subjective salience, and salience for children with ADHD is a dwindling resource that requires continuous replenishment, either from the task or from the environment. A recent study by Pelham et al. (1994) lent support to this notion: The authors reported that the academic seatwork of children with ADHD decreased significantly over time when there was no distractor or when a TV was on, but did not fall off when rock music on a radio channel selected by the children was playing.

Finally, it is important to emphasize that the order effect reported here, though quite substantial, was based on a small number of children. Replications with larger sample sizes are needed to cross-validate the findings. Additionally, to help verify whether the improvements found with music are specific to youngsters with ADHD, it would be useful to include other clinical contrast groups, such as students without ADHD who are relatively weak in arithmetic. Nevertheless, the current findings are in accord with several other studies noted previously and do not support the view that distractibility is an invariable hallmark of ADHD that results in impairment. Rather, depending on the situation, a presumed distractor like music may facilitate performance, rather than interfering with it. As others have noted (Douglas, 1983; Whalen, 1989), further research is required to evaluate the unique and combined influence of such factors as type (e.g., visual vs. auditory) and novelty of distractors; task content (e.g., arithmetic, spelling, reading) and difficulty level; length of task; and presence or absence of the experimenter (see Gomez & Sanson, 1994; Prior et al., 1985) on task performance. Studies of this sort would help to clarify which stimuli, under which task parameters, operate as facilitators or distractors in youngsters with ADHD. In so doing, they would also serve as further tests of the hypothesized arousal effects of stimulation on children with ADHD.

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AUTHORS' NOTES

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