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Task Demands Interact With the Single and Combined Effects of Medication and Contingencies on Children With ADHD

Leanne Tamm
Children's Hospital of Orange County and University of California, Irvine
Caryn L. Carlson
University of Texas at Austin

Objective: To investigate single and combined effects of stimulant medication and contingencies on the performance of ADHD children with tasks involving different cognitive demands. **Method:** Children diagnosed with ADHD participated in a within-subjects design. At two separate sessions, children on either medication or placebo (administered in a double-blind fashion) completed two tasks, a match-to-sample task and a stop-signal task, under three conditions (reward, response cost, and no contingency) in a counterbalanced order. **Results:** Contingencies and medication administered singly improved performance on both tasks. For the match-to-sample task, the combination of medication and contingencies was more efficacious than either alone. For the stop-signal task, the combination of medication and reward was no more effective than either alone; however, medication and response cost combined was more effective than either treatment alone. **Conclusion:** Results suggest that both medication and contingencies improve task performance. The findings suggest that task demands interact with single and combined treatment effects. *(J. of Att. Dis. 2007; 10(4) 372-380)*

Keywords: *ADHD; medication; reward; response cost; response inhibition*

The most common treatments for ADHD include stimulant medication and behavior therapy, the latter typically including contingency paradigms such as reward (R) and response cost (RC). Each of these individual treatment approaches has been demonstrated to improve behavioral and cognitive performance in children with ADHD, and the treatments are often assigned in combination. A large body of literature has examined whether combined approaches (i.e., stimulant medication and behavior therapy) are more efficacious for children with ADHD than either administered alone. Although a substantial number of these studies have demonstrated that medication is more potent than behavior therapy on the majority of dependent measures, at least in the classroom setting (Carlson, Pelham, Milich, & Dixon, 1992; Hechtman & Abikoff, 1995; Multimodal Treatment Study of Children With ADHD Cooperative Group, 1999; Pelham et al., 1993), there is a body of literature indicating that combined approaches are superior to either treatment alone (Hinshaw, Henker, & Whalen, 1984; Pelham & Waschbusch, 1999). Few studies, however, have examined how stimulant medication affects the individual components of global behavior therapy programs (i.e., those involving multiple components, such as parent training, daily report cards, etc.) and, in particular, the effects of medication on specific contingency paradigms (i.e., R and RC).

Only four large ($n > 16$) controlled experimental investigations examining the single and combined effects of stimulant medication and R and RC contingencies in an ADHD population were found in a review of the literature. Three of the studies used a reward-only condition (Arnett, Fischer, & Newby, 1996; Tripp & Alsop, 1999; Wilkison, Kircher, McMahon, & Sloane, 1995), and two included an R plus RC condition (Arnett et al., 1996; Solanto, 1990). Overall, the results of these studies suggest that both medication and contingency conditions when administered singly are effective in improving the performance of children with ADHD and that their combination is as effective (Solanto, Wender, & Bartell, 1997) or more effective (Arnett et al., 1996; Tripp & Alsop, 1999; Wilkison et al., 1995).

These conclusions are necessarily tentative, however, for a number of reasons. For example, Solanto et al.

(1997) did not find a main effect for contingency condition, which may be due to the fact that they did not use particularly salient rewards as incentives, which has been shown to effect outcome (Slusarek, Velling, Bunk, & Eggers, 2001). A no-contingency condition was not included in three of the studies (Arnett et al., 1996; Solanto et al., 1997; Tripp & Alsop, 1999), making it difficult to draw conclusions regarding the effects of contingencies or the effects of stimulant medication alone. The reward contingency schedule in the Tripp and Alsop (1999) study was intermittent, making it difficult to compare this study to the others. It also appears as though findings regarding the relative efficacy of medication combined with contingencies may be related to task demands and more specifically response inhibition. The combined medication and contingency condition was superior in the three studies using tasks that did not involve response inhibition (Arnett et al., 1996; Tripp & Alsop, 1999; Wilkison et al., 1995); in contrast, the combined medication and contingency condition was not superior in the fourth study, which used a task involving response inhibition (Solanto et al., 1997). Thus, performance on tasks that do not involve response inhibition may be more improved by the combination of medication and contingencies than on tasks that do involve response inhibition. Although there are no studies specifically investigating this hypothesis, there is evidence that medication specifically improves selective inhibition (Bedard et al., 2003; Scheres et al., 2003) and that this effect is large, possibly making it difficult to show additional effects of a contingency administered in conjunction.

A controlled examination of the interaction of medication and discrete contingencies such as R and RC may clarify conflicting reports regarding the single and combined effects of medication and contingencies. The purpose of this study was to investigate how contingencies (R and RC) and medication worked to affect performance alone and in combination. We selected two different tasks, one a stop-signal task and the other a match-to-sample task, to allow us to investigate whether differential task demands are contributing to the unclear findings regarding the relative efficacy of combined medication and contingency conditions. We hypothesized that medication would improve the performance of children with ADHD on both types of tasks and that the combination of medication and either R or RC would be more effective in improving performance than medication alone. We further speculated that the combination of medication and contingencies would be more efficacious for the task that did not involve response inhibition (match-to-sample task).

Method

Participants

Participants for this study included 19 children, ages 7 to 12, who were either participating in a separate clinical trial assessing the safety and efficacy of d-threo-methylphenidate (MPH; $n = 14$) or who were currently receiving dl-MPH (Ritalin; $n = 5$) to treat their ADHD symptoms. This sample was predominantly male, Caucasian, and from mid- to upper socioeconomic status (SES) as assessed using Duncan's Sociometric Index (Stevens & Featherman, 1981). Families received $20 for participating in the study, and children kept their earnings from the experimental tasks (see below for details). Demographic characteristics of the sample are reported in Table 1.

Parents of participants either completed a structured clinician-administered interview, the Diagnostic Interview Schedule for Children (participants recruited from clinical trial), or a semistructured *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; American Psychiatric Association, 1994) diagnostic interview to confirm their diagnosis of ADHD and to assess for oppositional defiant disorder (ODD) and conduct disorder (CD; participants recruited from physicians office). Children were included in the study if they had a primary diagnosis of ADHD–combined type and parent confirmation of early age of onset, chronicity, and pervasiveness of symptoms, and were excluded if they met criteria for other psychiatric disorders (except ODD or CD). Children were excluded from the study if taking psychotropic medication other than stimulant medication.

Each child enrolled in the study had been receiving medication to manage their ADHD twice daily for at least 2 months. Medication dosages ranged from 5mg to 30mg per day (d-threo-MPH $M = 7.68$mg; dl-MPH $M = 18$mg; note: a 5mg dose of d-threo-MPH is roughly equivalent to 10mg of dl-MPH). Children observed an 18-hr washout of their medication prior to both experimental sessions.

Children were administered the Vocabulary and Block Design subscales of the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991), from which a prorated IQ score was obtained (Sattler, 1992). The estimated IQ score obtained using these two subtests has been found to have satisfactory reliability and to correlate adequately with Full Scale IQ ($r = .86$; Sattler, 1992). Only children with a Full Scale IQ estimate of 80 or higher were included. This criterion was established to ascertain that the children were of sufficient cognitive functioning level to understand the instructions and perform the tasks.

Table 1
Demographic and Participant Characteristics

Variable	*M*	*SD*	%
Age (in years)	9.1	1.6	
Socioeconomic status	52.9	13.2	
Gender ratio			89% male
Ethnicity			84% Caucasian 10% African American 5% Hispanic
Comorbid oppositional defiant disorder			42%
Comorbid conduct disorder			5%
WISC-Full Scale IQ Score (prorated)	112.5	17.1	
WRAT-3 Mathematics	105.5	12.8	
Reading	108.2	12.5	
Spelling	100.3	13.6	
Percentage learning disability[a] – math			5% (n = 1)
Percentage learning disability[a] – reading			5% (n = 1)

Note: WISC = Wechsler Intelligence Scale for Children; WRAT-3 = Wide Range Achievement Test-Revision 3.
a. Learning disability designation was based on specific study criteria (below average achievement and a significant discrepancy between IQ and achievement). See text for more details.

The Wide Range Achievement Test-Revision 3 (WRAT-3; Jastak & Wilkinson, 1993) was administered to assess academic functioning. Some studies have suggested that learning disabilities (LDs) may negatively affect the performance of children on cognitive tasks (Sattler, 1992), and because ADHD has a high comorbidity with LD (Biederman, Faraone, & Lapey, 1992), study criteria were used to assign LD diagnoses. Specifically, LD was defined conservatively as below average achievement (i.e., achievement score < 85) and a significant discrepancy between IQ and achievement scores (i.e., difference of more than 1 standard deviation, i.e., 15 points, between IQ and achievement). Using these criteria, only one child was classified as having an LD; this child met LD criteria in both reading and math.

Experimental Tasks

Crazy Symbols is a match-to-sample task in which the child is presented with a target set of symbols (five individual symbols) to be matched with one of eight choices of figure sets positioned circularly around the target figure. This task was selected because it has previously been used in a study investigating the relative efficacy of R and RC contingencies, because it is considered an analog to low interest problem-solving activities in the classroom setting (Carlson & Tamm, 2000), and because it does not involve response inhibition.

Ice Cream is a stop-signal task previously used by Jennings, van der Molen, Pelham, Debski, and Hoza (1997), which requires children to perform a speeded reaction to a "go" signal after a fixed warning and preparatory interval. An auditory stop signal was randomly presented on 30% of the trials, to which participants were required to inhibit their responses. The stop-signal task is presented in a video game format; that is, visual display of an ice cream cart on a street corner with a stop light that turned green for go and an auditory sound of a car honking as the stop signal.

During both tasks, children received computerized visual and auditory feedback for accurate and inaccurate performance. Both tasks took approximately 5 min per contingency condition to complete.

Contingencies

Children performed both tasks under three contingency conditions. In the R condition, children received money (a quarter in Crazy Symbols and a dime in Ice Cream) for each correct trial (correctly matching, successfully inhibiting). In the RC condition, children were given $10 and were costed (a quarter in Crazy Symbols and a dime in Ice Cream) for each incorrect trial (incorrect matching, unsuccessful inhibition). In the no contingency (NR) condition, children did not earn or lose money for correct and incorrect responses.

Although perfect performance on the R and RC conditions earned $9.40 on the Ice Cream task, children were told they could earn up to $10, as on Crazy Symbols. Thus, the children believed the potential earnings for the two tasks were "equated," and in actuality, it was not possible for children to achieve perfect performance

because of specific task limitations designed to avoid ceiling effects. Children were timed out in the Crazy Symbols task, and reaction time requirements were specifically calculated for the Ice Cream task such that a challenging level was achieved (i.e., about 20% failure to inhibit after the stop signal).

Participants were randomly assigned to one of six combinations of the three contingency conditions: R/NR/RC, RC/R/NR, NR/R/RC, NR/RC/R, RC/R/NR, and RC/NR/R. Children were assigned a different combination of contingency conditions for each task such that a child might be assigned R/NR/RC for Crazy Symbols and NR/R/RC for the Ice Cream task, on both days, and there were at least two children in every combination of contingency conditions.

Procedure

Following a brief practice session, during which the child was oriented to the study procedures and exposed to the tasks, children attended two individual experimental testing sessions, which were scheduled at least 4 days apart. At the beginning of the session, children received either a placebo or their regularly prescribed dose of d-threo-MPH or dl-MPH, which was administered in a double-blind fashion. Specifically, the medication and placebo pills, which were similar in color, size, and overall appearance, were placed into small envelopes by a research assistant and labeled by session and ID number. A different research assistant who was blind to condition administered the pill at the beginning of the session. Following the administration of medication, either the WISC-III subtests or the WRAT-3 subtests were administered in a counterbalanced order across subjects. This procedure allowed for an adequate time period (approximately 30 min) to elapse so that children were within the "pharmacological window" for medication effects when they completed experimental tasks. The child received the appropriate instructions (R, RC, or NR) for either the Ice Cream or Crazy Symbols task, which were administered across days in a counterbalanced order.

Results

Dependent Variables

For Crazy Symbols, percentage correct (number correct divided by number attempted) was examined. For the Ice Cream task, performance measures included an estimated average stop-signal reaction time (SSRT) for correct trials (total of 28 possible correct) using the method described by Logan and Cowan (1984). Only the reaction times for correctly executed trials (stop) were examined to investigate processes involved in making an accurate response and to control for the possible strategy of withholding a response in an attempt to increase the probability of inhibition, thereby artificially decreasing reaction time data. Percentage correct was also examined (number correct divided by number of trials, or 94).

Analytic Strategy

For each of the dependent variables, outlier analyses were conducted. An outlier was defined as data representing values more than 3 standard deviations above or below the relevant mean scores. No outliers were observed. Data from two children were excluded in the analyses because of missing data in one or more conditions.

For the dependent variables, 2 (Drug: Medication, Placebo) X 3 (Condition: R, RC, NR) repeated measures MANOVAs were conducted. Follow-up analyses were conducted using paired samples *t* tests.

Finding comparable dependent variables on which to assess relative task performance proved difficult. The percentage correct variables are not directly comparable because the tasks were not equated for difficulty. The Ice Cream task was specifically modified to make the task challenging (about 20% failure rate), whereas the Crazy Symbols task was not. Furthermore, there was a set number of trials in the Ice Cream task (participants completed all 94 trials) but not the Crazy Symbols task (participants could attempt up to 40 trials but were often timed out before that point).

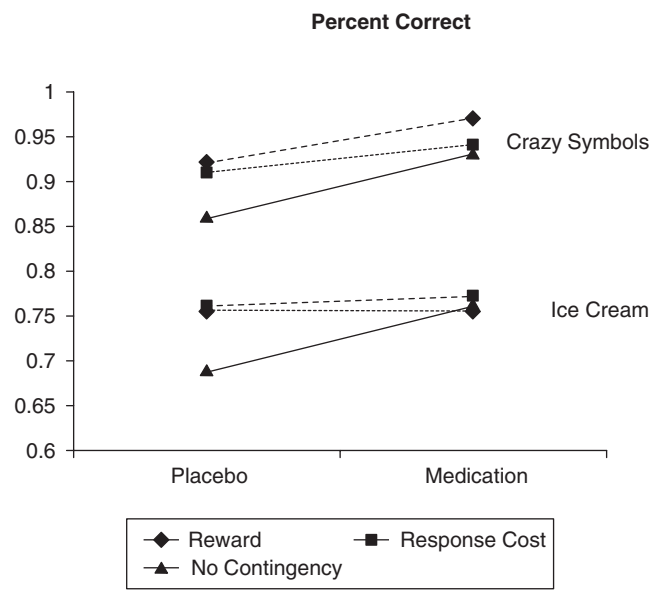
However, one index of relative impact of treatment conditions is effect sizes, which can be directly compared to one another. Thus, to further illuminate the magnitude of observed effects of contingencies, medication, and combined medication plus contingency conditions, effect size comparisons were conducted for the Crazy Symbols percentage correct variable and the Ice Cream SSRT variable. Effect sizes were calculated using the following formula: $d = (M\ 1 - M\ 2)$/pooled average standard deviation for each variable. To assess the magnitude of medication effects, effect sizes were calculated for the placebo + NR condition versus the medication + NR condition. To assess the magnitude of the effect of contingencies, effect sizes were calculated for the placebo + NR condition compared to the placebo + RC and placebo + R conditions. Comparisons between placebo R and RC and medication R and RC were also conducted to assess the relative benefits of R and RC. Finally, to address the effects of combined medication + contingency conditions, effect sizes were calculated between the placebo + NR condition and the medication + R and medication + RC conditions.

Table 2
Task Performance

Variable		Medication *M* (*SD*)	Placebo *M* (*SD*)	*F* Ratio For Drug	*F* Ratio For Condition	*F* Ratio For Interaction
Crazy symbols						
Percentage correct	Reward	.97 (.04)	.92 (.09)	3.02	3.45 (*P* = .059)	1.19
(*n* = 17)	Response cost	.94 (.08)	.91 (.10)		R > RC	
	No contingency	.93 (.21)	.86 (.22)			
Ice Cream						
SSRT (*n* = 12a)	Reward	267.42 (69.66)	262.40 (57.12)	4.18 (*p* = .06)	1.82	2.76
	Response cost	253.32 (76.80)	287.26 (87.31)	M < P		M: R = RC = NR
	No contingency	271.76 (86.57)	332.19 (106.14)			P: NR > R
Percentage correct	Reward	.76 (.10)	.76 (.10)	1.78	2.94	3.73*
(*n* = 17)	Response cost	.77 (.15)	.76 (.08)			M: R=RC=NR
	No contingency	.76 (.10)	.69 (.09)			P: R,RC > NR

Note: M = medication; P = placebo; R = reward; RC = response cost; NR = no contingency; SSRT = Estimated stop signal reaction time
a. *n* = 12, as there were 2 participants with missing data and 5 participants who did not get any stop trials correct.
*$p < .05$.

Figure 1
Percentage Correct for Both Tasks



Note: The Ice Cream task was modified so that participants would fail on approximately 20% of trials; no modification was made for the Crazy Symbols task.

Performance Variables

Crazy Symbols. For the percentage correct variable, no significant main or interaction effects were obtained. However, there was an almost significant ($p = .06$) effect of condition, with performance in the R condition significantly higher than in RC, $t(16) = 2.14$, $p = .048$, and for performance in the R condition to be almost significantly higher than that of NR, $t(16) = 2.01$, $p = .062$. Mean scores and standard deviations, along with MANOVA results, are shown in Table 2. The percentage correct variable values are depicted in Figure 1.

Ice Cream task. For the analysis of SSRT, no main or interaction effects were significant. The *n* for this variable was only 12, however, because of 2 children with missing data and 5 children who did not get any trials correct following the stop signal on one or more conditions; thus, the power on this variable was likely not sufficient to detect differences at the .05 level. However, there was an almost significant ($p = .06$) effect of medication, with reaction times in the placebo condition somewhat slower than in the medication condition.

Analyses of the percentage correct variable revealed a significant Drug X Condition interaction. Follow-up comparisons indicated that the three contingency conditions did not differ significantly from one another in the medication condition. In contrast, for the placebo condition, percentage correct was significantly lower in NR than in R, $t(16) = 2.59$, $p = .02$, and RC, $t(16) = 3.21$, $p = .01$, which did not significantly differ from each other. Furthermore, comparisons between contingency conditions on medication versus placebo revealed that children earned a higher percentage correct when medicated than when on placebo in the NR condition, $t(16) = 2.32$, $p = .034$, but no significant differences between medication and placebo performance emerged under R and RC conditions. This interaction is graphically presented in Figure 1. Mean scores and standard deviations, along with MANOVA results, are shown in Table 2.

Table 3
Selected Effect Size Comparisons (*d*)

	Crazy Symbols Percentage Correct	Ice Cream SSRT
Medication effects		
NR + P vs. NR + M	.33	.63
Contingency effects		
NR + P vs. R + P	.39	.85
NR + P vs. RC + P	.31	.46
R + P vs. RC + P	–.11	.34
Combined medication + contingency effects		
NR + P vs. R + M	.85	.74
NR + P vs. RC + M	.53	.86
R + M vs. RC + M	–.50	.19

Note: NR = no contingency; R = reward; RC = response cost; P = placebo; M = medication; SSRT = estimated stop signal reaction time. Effect size: > .2 = small; > .5 = medium; > .8 = large; $d = (M\ 1 - M\ 2)$/ pooled average standard deviation per variable.

Selected Effect Size Comparisons

Medication effects. These comparisons reveal that medication had a small effect (d = .33) to improve performance on Crazy Symbols (percentage correct) and a medium effect (d = .63) to improve inhibition on the Ice Cream task (SSRT).

Contingency effects. Both R (d = .39) and RC (d = .31) had a small effect on improving percentage correct for the Crazy Symbols task. In contrast, for the Ice Cream task, there was a large effect for R (d = .85) and a small effect for RC (d = .46) to improve SSRT.

Combined medication + contingency effects. On Crazy Symbols, R + medication showed a large effect (d = .85) and RC + medication a medium effect (d = .53) on percentage correct relative to no treatment; there was a medium effect for superiority of R + medication compared to RC + medication (d = –.5) on percentage correct for Crazy Symbols. For the Ice Cream task, there was a medium effect for R + medication (d = .74) and a large effect for RC + medication (d = .86) to improve inhibition as indexed by SSRT. The difference between R + medication and RC + medication was negligible for the Ice Cream SSRT variable. The results of all effect size comparisons can be viewed in Table 3.

Discussion

The current study was designed to investigate the single and combined effects of stimulant medication and contingencies on the performance of children with ADHD. Both a stop-signal (requiring response inhibition) and a match-to-sample task were included to examine whether conflicting findings from previous investigations might be clarified by considering task demands. Additionally, both R and RC conditions were included to examine whether the type of contingency interacted with efficacy and medication. This discussion primarily focuses on examination of the effect size findings, as the repeated measures MANOVAs were not significant, with the exception of a significant interaction for stop-signal percentage correct. Effect sizes are reasonable estimates of "clinical significance" and not as dependent on sample size (Swanson et al., 2001).

Effects of Medication

Repeated measures MANOVAs revealed a significant interaction for the stop-signal percentage correct variable, with medication improving performance compared to placebo. Effect size analyses revealed a stronger effect of medication on performance of the stop signal (medium effect size, d = .63) than the match-to-sample (small effect size, d = .33) task. The effect sizes of medication on performance observed in this study were within the expected range for the two tasks and consistent with the ranges reported in a meta-analysis examining the effects of medication on experimental tasks including measures of attention and concentration (Kavale, 1982). Specifically, the effect size observed in the meta-analysis for the task most similar to the match-to-sample task, the Kagan Matching Familiar Figures Test, was .19, whereas effects on continuous performance or vigilance tasks and reaction time tasks (.56 and .35, respectively) were closer to the effects observed for the stop-signal task (Kavale, 1982). Thus, consistent with previous research, our findings suggest that the nature of task demands directly affect the efficacy of medication on performance measures.

Effects of Contingency

Examination of contingency effects using repeated measure MANOVA reveals that both R and RC improved performance for the stop-signal task relative to NR (significant interaction for the stop-signal percentage correct variable). Effect size analyses revealed stronger effects for R (d = .85) than RC (d = .46) on the stop-signal task. For the match-to-sample task, effect size analyses revealed a small effect for both R and RC, which did not differ from one another.

Combined Effect of Medication and Contingencies

Analyses examining Drug X Contingency interactions for each task did not suggest additional gains beyond those attained with medication alone. The significant Drug X Contingency interaction for the stop-signal percentage correct variable revealed that both contingencies were equally as effective as medication in improving performance, compared to no treatment.

The tasks, however, could not be directly compared using repeated measures MANOVA. Thus, the effect size comparisons are particularly illuminating with regard to the combined effects of medication and contingencies for the two tasks. The results indicate that efficacy of combined conditions is affected by task demands and contingency type.

For the match-to-sample task, the combination of medication and contingencies was more effective in improving performance than either treatment alone. In fact, the effect size for the combined treatment conditions was large for R + medication (d = .85) and medium for RC + medication (d = .53), compared to a small effect size for either treatment alone (M effect d = .33; R effect =.39; RC effect d = .31). This is strong evidence of an "additive effect" on performance with combined medication + contingency conditions, such that combined effects equal the total of the individual components (Pelham & Murphy, 1986; Pelham & Waschbusch, 1999).

In contrast, for the stop-signal task, the impact of combined medication and contingency conditions is less clear. It appears that there is actually a slightly stronger effect for R alone (d = .85) than for the combined R + medication (d = .74) or medication alone (d = .63) conditions. Tentatively, this suggests that for the stop-signal task, there was an "inhibition effect" (such that the two individual components interact to yield an effect that is less than one or the other component) for the combined R + medication condition (Pelham & Murphy, 1986; Pelham & Waschbusch, 1999). In contrast, the combined RC + medication condition (d = .86) was superior to either medication (d = .63) or RC (d = .46) alone and consistent with an "additive effect."

Overall, with regard to the combined effect of stimulant medication and contingency conditions, the results are consistent with the two experimental studies that could be directly compared to this study. These two studies directly compared R or R + RC to combined medication plus contingency conditions (Solanto et al., 1997; Wilkison et al., 1995). The tasks used in the Wilkison et al. (1995)—a button pressing task, requiring progressively more button presses to earn rewards—and Solanto et al. (1997)—a continuous performance task (CPT)—studies were markedly different in nature to those used in this study; however, the former did not require response inhibition, whereas the latter did. For the task not requiring response inhibition, a comparison of R only with a combined R plus medication condition revealed the most gains in the combined condition (Wilkison et al., 1995). In contrast, for the CPT task requiring response inhibition, a comparison of R and R + RC, with and without medication, there was a trend toward an effect of contingency condition, but the addition of contingencies did not improve performance beyond gains achieved with medication (Solanto et al., 1997). However, it is not possible to address the relative efficacy of R versus RC combined with medication for the Solanto et al. (1997) paper, as the R + RC conditions were combined. The current results suggest that it is important to investigate the utility of discrete contingencies (R & RC versus combined R + RC conditions), as the findings regarding the relative efficacy of the two combined conditions (R + M and RC + M) show a different pattern of results.

The fact that the gains observed in the combined medication plus contingency conditions were additive for the match-to-sample and stop signal (for the RC + M condition only) tasks was not unexpected. The majority of studies have reported greater behavioral gains with combined behavior therapy/pharmacological treatment programs than either individual behavioral or pharmacological treatment programs alone, with gains in effect size ranging from .3 to .4 (Pelham & Fabiano, 2000). In our study, the gains in effect size for combined versus single treatment conditions ranged from .11 to .52 and suggests that, in general, the combination of the contingency and pharmacological interventions were more efficacious than either alone. The one exception was for the stop-signal SSRT variable, which showed an inhibitory effect (worse performance for the combined M + R condition). This finding was not predicted and suggests that further examination of the interaction between inhibition and RC contingencies is warranted.

Clinical Implications

Because contingency management programs are often promoted as a viable treatment for children with ADHD in the school setting, it is important to note that one would expect a relatively small performance improvement on traditional academic tasks, which do not typically directly require response inhibition. Similarly, medication, when administered alone, may not have a particularly large effect on improving academic performance. Thus, for academic tasks, it appears that the

application of a reward-based contingency program in combination with medication may have the most significant positive impact on typical academic tasks (reading, math problems, etc.).

These findings also strongly support the hypothesis that task demands mediate the impact of medication and contingencies on performance. Accordingly, research explicating the nature of cognitive mechanisms underlying the acquisition of academic skills will be critical in understanding single and combined effects of medication and contingencies on classroom learning.

Limitations and Caveats

Despite the within-subjects design and every effort to minimize subject variability, the sample size was relatively small and comprised two different subgroups (children receiving d-threo-MPH and dl-MPH, $n = 5$). Children enrolled in the d-threo-MPH study were more thoroughly screened for other pathology and excluded if they met criteria for comorbid mood or anxiety disorders, whereas the children receiving dl-MPH were primarily screened to ensure they met criteria for ADHD. Thus, although unlikely, these two subgroups may have differed somewhat, thus increasing error variance. A review of mean dependent variable scores for the two groups did not reveal a consistent pattern of differences, however, and the pattern of results obtained was similar when the children on dl-MPH were excluded from analyses.

Another limitation was imposed by task differences that did not allow direct statistical comparison across tasks on a similar outcome variable. Furthermore, the lack of a control group is problematic, as the ability to compare the current task findings to previous findings is limited, particularly for the stop-signal task. The sample size was modest but adequate for detecting small effect sizes (Cohen, 1992); however, there were a number of trend findings that reflect limited power and the need for cautious interpretation and future replication. Finally, the sample primarily comprised a mid- to upper-level SES, primarily male, and intellectual functioning at the upper end of the average range, and the findings should not be generalized beyond similar individuals until the results are confirmed and replicated with other samples of a broader clinical and ethnic range.

Conclusion

The current findings support the hypothesis that differences in task demands are contributing to the effects of medication and contingencies in improving performance. Both medication and contingencies, when administered singly, were more efficacious in improving performance on the stop-signal task, which involved response inhibition, than the match-to-sample task. An additive effect was observed for the task not involving response inhibition such that the combination of medication and contingencies was more efficacious than either alone. R alone was most efficacious in improving performance on the stop-signal task (involving response inhibition), and R plus medication was the most efficacious for the match-to-sample task (not involving response inhibition). In considering what combinations of medication and behavioral intervention are optimal, clinicians and researchers should be aware that the answer to this question may be directly related to demands placed by the outcome tasks of interest.

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Leanne Tamm received her PhD in clinical psychology at the University of Texas at Austin. After completing her postdoctoral fellowship at Stanford University School of Medicine, she became the codirector of the Children's Hospital of Orange County (CHOC) and University of California, Irvine (UCI), Initiative for the Development of Attention and Readiness Program at CHOC and UCI. She is an assistant professor in the clinical track at UCI. Her research concerns treatment and executive and brain function in ADHD.

Caryn Carlson received her PhD in psychology from the University of Georgia. After completing postdoctoral work at Indiana University, she was a faculty member in the psychology department at Virginia Tech for 3 years before joining the faculty at the University of Texas at Austin, where she is currently a professor and director of clinical training. Her research program, which has been funded by the National Institutes of Mental Health, has examined numerous aspects of the functioning of children with ADHD, including the effects of contingencies on performance and motivation, ADHD–predominantly inattentive type, comorbidity, and social, cognitive, and attentional correlates of ADHD.