

## Response Inhibition and Measures of Psychopathology: A Dimensional Analysis

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### ABSTRACT

On the basis of Quay's (1988a, 1988b, 1993, 1997) model in which the Behavioral Inhibition System (BIS) and the Behavioral Activation System (BAS) are linked to various forms of child psychopathology, predictions were made regarding the relation between inhibitory control and two dimensions of psychopathology: externalizing and internalizing behavior. Inhibitory control was measured using two versions of Logan and Cowan's stop signal paradigm (1984; Logan, Cowan, & Davis, 1984; Osman, Kornblum, & Meyer, 1986, 1990). The primary outcome measure for the stop tasks was stop signal reaction time (SSRT) which measures the latency of the inhibition process. A positive relationship was predicted for externalizing behavior, whereas a negative relationship was predicted for internalizing behavior. A total of 42 non-clinical elementary school children, in the age range of 6 to 12 years, participated in the study. Externalizing behavior was positively related to response inhibition. Symptoms of ADHD seem to be better at predicting inhibitory functioning than symptoms of aggressive behavior disorders. Some support was found for a negative relation between internalizing behavior and inhibitory control. These findings support Quay's model and the discriminant validity of inhibitory control with regard to externalizing and internalizing behavior.

Achenbach and Edelbrock's (1978) review of the literature on child psychopathology, led to a now well recognized categorization of problem behavior into two dimensions: externalizing behavior and internalizing behavior. Children with externalizing behavior show undersocialized and aggressive tendencies, as seen in children with Attention Deficit Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD). Children with internalizing behavior are shy, seclusive and withdrawn. These symptoms characterize anxiety disorder and depression (Achenbach & Edelbrock, 1978). Numerous studies have since yielded further support for the distinction between internalizing and externalizing behavior, including recent studies by Cantwell (1996) and Hartman et al. (1999).

Internalizing and externalizing behavior were described by Quay (1988a, 1988b, 1993, 1997)

in terms of the (in)ability to inhibit behavior. Quay's descriptions were based on Gray's (1987) neuropsychological model of brain functioning. In Gray's model, behavior is seen as resulting from the activation of two different brain systems. One is the Behavioral Activation System (BAS) which is sensitive to signals of reward. The other is the Behavioral Inhibition System (BIS) which is sensitive to signals of punishment. Activation of the BIS inhibits behavior, whereas activation of the BAS initiates behavior. Whether behavior is inhibited or initiated depends on the current activity of the two systems. A BIS that is more active than the BAS will increase the likelihood of behavior to be inhibited. A BAS that is more active than the BIS will cause behavior to be initiated more readily.

According to Quay (1988a, 1988b, 1993, 1997), the excessive amount of uninhibited be-

havior seen in externalizing behavior can be accounted for by various disturbances in the balance between BIS and BAS activity. One possibility is that children with externalizing behavior have a permanently underactive BIS, causing the BAS to initiate inappropriate behavior which would normally be inhibited by the BIS. Another possibility is that children with externalizing behavior have a permanently overactive BAS which causes it to prevail over the BIS, again resulting in lack of control over inappropriate behavior. A third possibility involves a combination of both: a permanently underactive BIS and a permanently overactive BAS. Consequently, children with externalizing behavior would show an inability to inhibit responses, when compared with normal children.

Internalizing behavior, on the other hand, could be attributed to a consistently overactive BIS, which causes behavior to be inhibited, even in cases where this is not appropriate (Quay, 1988a, 1988b). Individuals who inhibit their responses too readily would be expected to be passive or avoidant, i.e., to show internalizing behavior. Compared with normal children and children with externalizing behavior, children with internalizing behavior show an enhanced ability to inhibit responses.

The concept of inhibitory control is also used to account for more specific categories of psychopathology within the dimensions of internalizing and externalizing behavior. Douglas (1988) and Barkley (1994, 1997), among others, suggested that a deficiency in the ability to inhibit behavior is the central deficit in ADHD. Quay (1988a, 1988b, 1993) argued that CD is associated with a heightened sensitivity to cues for reward, leading to an increase in BAS activity. Since the BAS activates behavior, this in turn will interfere with the capability for response inhibition. A number of investigations into the temperamental trait of inhibition showed that children high on this trait, are at increased risk to develop childhood anxiety disorders later in their lives (see for a review Oosterlaan, 2000). Furthermore, Quay (1988a, 1988b) suggested that over-inhibition could even be the underlying cause of anxiety disorders.

In order to investigate the possible relation between inhibitory control and psychopathology, different measures of inhibitory control have been developed, including the so-called stop signal paradigm (Logan & Cowan, 1984; Logan, Cowan, & Davis, 1984). Several studies have supported the validity of this task as a measure of response inhibition (e.g., Tannock, Schachar, Carr, Chajczyk, & Logan, 1989). The primary outcome measure of the stop task is stop signal reaction time (SSRT), which is an estimate of the speed of the inhibitory process. Briefly, the stop task requires fast and accurate execution of a reaction time task (go task). Occasionally, a 'stop signal' is presented, which requires the child to inhibit the response to the go task. The delay between the onset of the stimulus which signals the child to react (the 'go signal') and the stop signal can be varied to increase or decrease the level of difficulty. The larger the delay between go and stop signal, the harder it becomes for the child to withhold his or her response.

The stop task has been used in several studies to measure inhibitory control in children with externalizing behavior (Aman, Roberts, & Pennington, 1998; Daugherty, Quay, & Ramos, 1993; Jennings, Van der Molen, Pelham, Brock, & Hoza, 1997; Logan, Schachar, & Tannock, 1997; Oosterlaan & Sergeant, 1996, 1998a, 1998b; Pliszka, Borcharding, Spratley, & Leon, 1995; Schachar & Logan, 1990; Schachar & Tannock, 1995; Schachar, Tannock, Marriott, & Logan, 1995). In a recent meta-analysis, Oosterlaan, Logan and Sergeant (1998) reviewed these studies and found that normal control children usually outperformed children with ADHD and children with ODD or CD. For children with ADHD, differences with normal control children were most marked (average effect size,  $d = .64$ ). Some studies, however, found no significant differences (Daugherty et al., 1993) or had inconclusive results (e.g., Jennings et al., 1996). For children with ODD and CD, differences with normal control children were less conclusive (average effect size,  $d = .51$ ). Some studies found supporting evidence for the notion of decreased inhibitory control in children with ODD or CD (Oosterlaan & Sergeant, 1996, 1998a). In

other studies, no group differences were observed (Schachar & Logan, 1990; Schachar & Tannock, 1995; Daugherty et al., 1993).

The few studies that investigated the possible link between inhibitory control and internalizing behavior (mainly anxiety) yielded virtually no support for the hypothesis of enhanced inhibitory control in children with internalizing behavior (Daugherty et al., 1993; Oosterlaan & Sergeant, 1996, 1998a, 1998b).

In most studies using the stop task, a categorical approach to childhood psychopathology was used. Milich, Hartung, Martin, and Haigler (1994) give two reasons why a dimensional approach is preferable in this field of research. First, the dimensional approach more accurately reflects the nature of psychopathology, in that it does not require the arbitrary dichotomization of individuals into categories, as is done in previous studies using the stop task. Second, this approach offers a more powerful statistical test because dichotomizing continuous measures results in the loss of potentially useful information. The aim of the present study, therefore, was not to focus on specific categories of psychopathology, but to investigate whether two broad dimensions of psychopathology, internalizing and externalizing behavior, were related to inhibitory control. It was hypothesized that internalizing behavior would show a positive relationship with inhibitory control, whereas externalizing behavior would show a negative relationship with inhibitory control.

## METHOD

### Participants

Four regular elementary schools agreed to participate in this study. All parents from children in grades 2–7 ( $N = 772$ ) were sent a letter explaining the aims of the study and an informed consent form. In addition, two questionnaires were included for the parents to fill out: the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Van den Ende, & Koot, 1996a) and the Disruptive Behavior Disorder rating scale (DBD rating scale; Oosterlaan, Scheres, Antrop, Roeyers, & Sergeant, 2000; Pelham, Gnagy, Greenslade, & Milich, 1992). Fifteen percent of

the parents ( $N = 119$ ) consented in participating in the study. Despite a low response rate, scores on all scales showed to be representative of a general population sample. Of the children whose parents gave permission for their children to participate in the study, 42 were randomly selected with the restriction that for each age there were six children; three boys and three girls. Children were aged between 6 and 12 years ( $M = 9.00$ ,  $SD = 2.02$ ).

The teachers of these children completed the Teacher Rating Form (TRF; Achenbach, 1991; Verhulst, Van den Ende, & Koot, 1996b) and the teacher equivalent of the DBD rating scale. For the teacher questionnaires, a return rate of 100% was obtained.

### Aggregate Measures of Internalizing and Externalizing Behavior

The CBCL is a widely used screening instrument which is used to measure various small-band dimensions of psychopathology as well as two broad-band dimensions of psychopathology: internalizing and externalizing behavior. The CBCL is to be completed by one of the child's parents. The TRF is the teacher equivalent of the CBCL. The DBD rating scale is comprised of items that refer directly to the criteria for ADHD, ODD, and CD from the fourth edition of the Diagnostic and Statistical Manual of mental disorders (DSM-IV; American Psychiatric Association [APA], 1994). There is both a parent and a teacher version of the DBD rating scale.

Since the CBCL and the TRF as well as the parent and teacher versions of the DBD are designed to measure the same constructs, scores on parent and teacher versions of the questionnaires were aggregated. This method of aggregating scores attenuates extreme scores: The impact of an extreme score from one of both informants can be tempered by a more modest score from the other informant. In this way, the method applied also emphasizes pervasiveness of behavioral problems reported by the informants. Scores were aggregated by transforming scale scores into  $z$ -scores and averaging these scores across scales and informants. The Internalizing Behavior composite score was obtained by aggregating the  $z$ -scores of the Internalizing Problems scales of the CBCL and TRF.

Externalizing Behavior was calculated by aggregating the  $z$ -scores on both the parent and teacher DBD scales CD, ODD, Inattention, and Hyperactivity/Impulsiveness as well as the CBCL and TRF Attention Problems, Aggressive Behavior, and Delinquent Behavior scales.

To assess whether more specific dimensions of child psychopathology would clarify the hypothesized relation between Externalizing Behavior and inhibitory control, the Externalizing Behavior dimension was reduced to two more specific dimensions: one dimension consisting of symptoms of ADHD (an aggregate of the *z*-scores on the Attention Problems scales of the CBCL and TRF, and the Inattention and Hyperactivity/Impulsivity scales of the parent and teacher versions of the DBD), and one dimension consisting of symptoms of aggressive behavior disorders (an aggregate of the *z*-scores on Delinquent Behavior and the Aggressive Behavior scales of the CBCL and TRF, and the ODD and CD scales of the parent and teacher versions of the DBD). These analyses were conducted on an exploratory basis because the limited number of subjects did not warrant additional predictors (above age, Externalizing Behavior, and Internalizing Behavior) to be entered in the regression analyses.

Medium-sized correlations (Cohen, 1988) were found between parent measures on the one hand, and teacher measures on the other: The correlation between Externalizing Behavior, as rated by parents, and Externalizing Behavior, as rated by teachers, was  $r = .39$  ( $p < .05$ ). The correlation between Internalizing Behavior, as rated by parents, and Internalizing Behavior, as rated by teachers, was  $r = .46$  ( $p < .01$ ).

### Stop Task

The stop task involved two types of trials: go trials and stop trials. At the start of a go trial, a fixation point (200 ms in duration) appeared on the computer screen. Next, an airplane was presented for 300 ms at the midpoint of the screen. If the front side of the plane pointed to the right, subjects were required to press the right response button. If the front side of the plane pointed to the left, subjects were instructed to press the left button. Between trials the screen turned blank for 1500 ms.

Stop trials were identical to go trials, but in addition a stop signal (a 1000 Hz tone, 50 ms in duration) was presented through earphones. The stop signal was usually presented shortly after the airplane, but could also be presented concurrently with or shortly before the plane, dependent on the child's performance (see below). Children were instructed not to press either button when the stop signal was presented. Seventy-five percent of the trials were go trials, and 25% were stop trials. Stop trials were presented randomly within each block. A stop trial was always followed by a go trial. However, to prevent children expecting a stop trial

always being followed by a go trial, two stop trials were presented in succession in each block.

Trials were presented in blocks of 64 trials. Within a block, the front side of the plane pointed equally often to the right or to the left. Stop signals were presented equally often on trials where planes pointed to the right, and trials where planes pointed to the left.

The task started with two practice blocks, to make sure that children were familiar with the paradigm. In the first block only go trials were presented. Children were encouraged by standardized instructions to respond as quickly and accurately as possible. In the second practice block, 25% of the trials were stop trials. Children were instructed to work as quickly as possible and to try to inhibit their response when they heard a stop signal. After practice, participants were administered four experimental blocks of 64 trials each, with a five-minute break between block two and three.

### Calculating SSRT

The dependent variable that reflects the latency of the inhibitory process is SSRT. This variable cannot be observed directly, because the response to a stop signal is a covert one. Therefore, SSRT has to be estimated. The procedures for estimating SSRT are based on a well-established theory of inhibition, known as the race model (Logan & Cowan, 1984; Logan et al., 1984; see for a review Logan, 1994). According to this model, response inhibition depends on a race between, on the one hand, the process underlying response execution and, on the other hand, the inhibitory process. This inhibitory process is triggered by information which signals a subject to discontinue or change a current course of action, such as an error during performance. If the inhibitory process runs to completion first, the response is inhibited. If the response execution process finishes first, the ongoing action is completed.

In this study, two methods for estimating SSRT were used. In the stop task as it was originally developed by Logan and colleagues (Logan & Cowan, 1984, Logan et al., 1984), stop signals are presented at predetermined intervals before the subject's expected response. In this way, the ability to inhibit a response at different points in the response execution process can be determined. The shorter the time interval between the stop signal and the expected response, the more difficult it becomes to inhibit the response. In this study, the length of this time interval was either 50 ms, 200 ms, 350 ms, or 500 ms. The length of these intervals was randomly varied.

For the stop task with *fixed intervals*, the following procedure was used to calculate SSRT. First, reaction times on go trials are rank ordered on a time axis. Reaction times are ordered from fastest to slowest. Second, the  $n$ th reaction time is picked, where  $n$  is defined by the product of the number of reaction times in the distribution and the probability of responding given a stop signal (or 1 minus the probability of inhibition). For example, if there were 100 reaction times in the distribution and the probability of responding given a stop signal was .3, the  $n$ th reaction time would be the 30th in the rank-ordered distribution. The  $n$ th reaction time is an estimate for the time at which the stop process runs to completion, relative to the onset of the go signal. Third, stop signal interval (the time interval between the stop signal and the subject's expected response) is subtracted from the  $n$ th reaction time to estimate SSRT. SSRT is calculated for each interval and then averaged.

Osman et al. (1986, 1990; Logan et al., 1997) adapted this procedure to allow for a more direct observation of SSRT. In this version of the stop task, the delay between the onset of the go signal and the stop signal is varied. For the stop task with *tracking mechanism*, SSRT can be observed almost directly. In the current study, the initial delay between go signal and stop signal was 250 ms. If the child succeeded in inhibiting his or her response, the delay on the next stop trial was increased by 50 ms. If the child did not succeed in inhibiting, the delay on the next stop trial was decreased by 50 ms. By using this tracking mechanism, it is established that a child has a 50% chance of response inhibition. This means that on average, the go and the stop process finish at the same time. In this way, the finishing time of the go process becomes an estimate of the finishing time of the stop process (SSRT). SSRT can be calculated by subtracting the mean delay from the mean go signal reaction time.

### Design and Procedure

The testing phase was spread out over three days. In order to be able to control for the potential influence of IQ on SSRT, IQ was estimated on day 1, using a short form of the Revised Wechsler Intelligence Scale for Children (WISC-R). Four subtests were used: Vocabulary, Arithmetic, Block Design and Picture Arrangement. These subtests were chosen on the basis of their high correlations with the full scale IQ ( $r = .93 - .95$ ; Groth-Marnat, 1997).

Children were administered two stop tasks on day 2 and 3, respectively. For all children, SSRT

was estimated both with the fixed intervals method and the tracking mechanism method. The order in which the subjects were administered the tasks was balanced. For half of the children, SSRT was estimated with the fixed intervals version first, followed by the tracking mechanism version. For the other half of the children, the order was reversed.

### Statistical Analyses

In order to assess whether age, IQ, and sex were associated with response inhibition, Pearson correlations were calculated between SSRTs for both stop tasks, on the one hand, and age, IQ, and sex (with male coded as 1 and female coded as 2), on the other hand. Age correlated with SSRT tracking ( $r = -.49, p < .01$ ), but not with SSRT fixed ( $r = -.09, ns$ ). All other correlations turned out to be nonsignificant (sex:  $r = .20, ns$ , and  $r = .10, ns$ , for SSRT fixed and SSRT tracking, respectively; IQ:  $r = .11, ns$ , and  $r = .03, ns$ , for SSRT fixed and SSRT tracking, respectively). In subsequent analyses, age was statistically controlled (see below).

To assess whether ratings of Externalizing and Internalizing Behavior could predict inhibitory functioning (SSRT), two separate multiple regression analyses were conducted. In the first regression analysis, SSRT fixed was the dependent variable, and in the second regression analysis, SSRT tracking was the dependent variable. Because of the significant correlation between age and SSRT tracking, age was always entered first (step 1), followed by Externalizing Behavior and Internalizing Behavior (step 2 and 3). The interaction between Externalizing Behavior and Internalizing Behavior was entered last (step 4). The order of the behavior dimensions was alternated. In model 1, Externalizing Behavior was entered at step 2 and Internalizing Behavior was entered at step 3. In model 2, Internalizing Behavior was entered at step 2 and Externalizing Behavior was entered at step 3. By applying model 1, the explanatory power of Internalizing Behavior over and beyond age and Externalizing Behavior was assessed. With model 2, the explanatory power of Externalizing Behavior over and beyond age and Internalizing Behavior was assessed.

In the exploratory analysis for SSRT fixed and SSRT tracking, age was always entered first in the regression (step 1), followed by Internalizing Behavior (step 2). ADHD and Aggressive Behavior were entered at step 3 and 4, respectively. The order of ADHD and Aggressive Behavior was alternated.

Table 1. Summary of Hierarchical Regression Analysis for Variables Predicting SSRT (N = 42).

Predictors	$R^2$	$\Delta R^2$	$B$	$SE B$	$\beta$
SSRT fixed					
Step 1, age	.01	.01	-.08	5	.00
Step 2, Externalizing Behavior	.03	.02	45	22	.45*
Step 3, Internalizing Behavior	.23	.20**	-46	15	-.57**
Step 2, Internalizing Behavior	.09	.08	-46	15	-.57**
Step 3, Externalizing Behavior	.23	.15**	45	22	.45*
Step 4, interaction <sup>a</sup>	.23	.00	3	19	.03
SSRT tracking					
Step 1, age	.24	.24**	-13	3	-.50**
Step 2, Externalizing Behavior	.28	.05	52	15	.67**
Step 3, Internalizing Behavior	.33	.05	-15	10	-.24
Step 2, Internalizing Behavior	.24	.00	-15	10	-.24
Step 3, Externalizing Behavior	.33	.09*	52	15	.67**
Step 4, interaction <sup>a</sup>	.44	.11**	-34	12	-.46**

Note. SSRT fixed = stop signal reaction time for the stop task with fixed intervals; SSRT tracking = stop signal reaction time for the stop task with tracking mechanism.

<sup>a</sup> Interaction between the Internalizing Behavior and Externalizing Behavior aggregate scores.

\*  $p \leq .05$ ; \*\*  $p \leq .01$ .

## RESULTS AND DISCUSSION

### Regression Analyses

The results for the regression analyses are shown in Table 1. Means and standard deviations for SSRTs and other measures derived from both stop tasks are presented in Table 2.

#### SSRT fixed

When the proportion of variance explained by age and Externalizing Behavior was taken into account, an additional 20% of the variance in SSRT fixed was explained by Internalizing Be-

havior ( $p < .01$ ). By inspecting the  $\beta$  coefficient for Internalizing Behavior, it was established that there was a negative relation between Internalizing Behavior and SSRT fixed ( $\beta = -.57$ ). This means that, in accordance with our hypotheses, children with high ratings of Internalizing Behavior generally showed fast SSRTs, that is, demonstrated enhanced response inhibition.

When the order of entry of the behavior dimensions was reversed, Externalizing Behavior explained an additional 15% of the variance in SSRT fixed, over and beyond the proportion of variance explained by age and Internalizing Be-

Table 2. Outcome Variables for the Two Versions of the Stop Task.

Outcome variables	Fixed intervals		Tracking mechanism	
	$M$	( $SD^a$ )	$M$	( $SD^a$ )
MRT (ms)	415	(86)	487	(78)
SD <sup>b</sup>	93	(31)	103	(33)
% correct	93.6	(3.9)	97.0	(3.6)
SSRT (ms)	222	(68)	147	(53)

Note. MRT: mean reaction time; SD: standard deviation of reaction times; % correct: percentage correct responses on go trials; SSRT: stop signal reaction time.

<sup>a</sup>Between subjects.

<sup>b</sup>Within subjects.

havior ( $p < .05$ ). Inspection of the  $\beta$  coefficient for Externalizing Behavior revealed a positive relation between ratings of Externalizing Behavior and SSRT fixed ( $\beta = .45$ ). Thus, children with high ratings of Externalizing Behavior generally showed slow SSRTs, indicating relatively poor inhibitory control. Our second hypothesis, a positive relation between Externalizing Behavior and SSRT, was therefore supported. The interaction between Externalizing Behavior and Internalizing Behavior was not found to explain a significant proportion of the remaining variance in inhibitory performance as measured by SSRT fixed.

#### *SSRT tracking*

When Internalizing Behavior was entered at step 3 in the regression analysis, it was found to explain 5% of the variance in SSRT tracking, but this effect was not significant ( $p = .12$ ). However, the direction of the relation was in line with what was expected: There was a negative, though nonsignificant, relation between Internalizing Behavior and the capability for response inhibition ( $\beta = -.24$ ).

When the order of the behavioral dimensions was alternated, Externalizing Behavior explained 9% of the variance in SSRT tracking ( $p < .05$ ). Inspection of the  $\beta$  coefficient revealed a positive relation between ratings of Externalizing Behavior and SSRT tracking ( $\beta = .67$ ). As with the fixed intervals version of the stop task, the hypothesized relation between Externalizing Behavior and SSRT was corroborated with the tracking version of the stop task. The interaction between Externalizing Behavior and Internalizing Behavior was found to explain an additional 11% of the variance in SSRT tracking over and beyond the proportion of variance explained by age, Externalizing Behavior and Internalizing Behavior ( $p < .01$ ). Inspection of the  $\beta$  coefficient revealed a negative relation between the interaction term for Externalizing and Internalizing Behavior, on the one hand, and SSRT tracking, on the other hand ( $\beta = -.46$ ). High ratings of Externalizing Behavior were predictive of poor inhibitory control (high values of SSRT tracking) in combination with low ratings of Internalizing Behavior only.

#### *Exploratory analyses*

ADHD appeared to be a better predictor for SSRT fixed than Aggressive Behavior. When ADHD was entered at step 4 in the regression analysis, it explained an additional 7% of the variance in SSRT fixed, though this result did not reach conventional levels of significance ( $p = .08$ ). Aggressive Behavior, on the other hand, could not account for any additional variance in SSRT fixed, ( $\Delta R^2 = .00$ , *ns*) over and beyond the predictive power of age, Internalizing Behavior, and ADHD.

For SSRT tracking, similar results emerged. ADHD entered at step 4 explained 4% of the variance in SSRT tracking, but this effect did not reach conventional levels of significance ( $p = .13$ ). Aggressive Behavior entered at step 4 did not explain any variance in SSRT tracking ( $\Delta R^2 = .00$ , *ns*).

In sum, our predictions concerning a possible relation between ratings of externalizing behavior and SSRT were confirmed with both versions of the stop task. A positive relation was found, implying that an increase in externalizing behavior will generally accompany an increase in SSRT. This, in turn, means that children who are observed to be frequently showing externalizing behavior will demonstrate poor inhibitory control. The results for internalizing behavior were inconclusive. Partial support was found for a negative relation between internalizing behavior, on the one hand, and SSRT on the other, implying that children with high levels of internalizing behavior will generally show an enhanced capability for response inhibition. The finding of a negative relation between the interaction for Externalizing Behavior and Internalizing Behavior, on the one hand, and SSRT tracking, on the other hand, suggests that poor inhibitory control is associated with high levels of externalizing behavior in combination with low levels of internalizing behavior only. However, inspection of scatterplots revealed that this interaction effect was due to a few cases only. Therefore, this finding should be interpreted with extreme caution.

Exploratory analyses revealed that breaking down the Externalizing Behavior dimension into two more specific dimensions of behavior (i.e.,

symptoms of ADHD and symptoms of aggressive behavior disorders) can be informative. Symptoms of ADHD seem to be a better predictor of inhibitory functioning than symptoms of aggressive behavior disorders, such as ODD and CD. These results have to be interpreted with much caution, however, bearing in mind the high number of predictors entered in the regression analysis, relative to the number of subjects. The results of this study relate to earlier studies that have investigated inhibitory control in children with disruptive behavior disorders. Oosterlaan et al. (1998), for example, found that differences between normal children and children with ADHD are more marked than differences between normal children and children with ODD or CD.

There are some discrepancies between the results obtained with the stop task with fixed intervals and the results obtained with the stop task with tracking mechanism. First, whereas the results for Externalizing Behavior are comparable for both methods of estimating SSRT, the results for Internalizing Behavior are not. For the stop task with fixed intervals, the relation between Internalizing Behavior and SSRT is stronger than for the stop task with tracking mechanism. Second, for the stop task with fixed intervals, the interaction between Externalizing Behavior and Internalizing Behavior does not explain any additional variance in SSRT, whereas for the stop task with tracking mechanism, the interaction between Externalizing Behavior and Internalizing Behavior explains an additional 11% over and above the proportion of variance explained by age, Externalizing Behavior, and Internalizing Behavior. As noted earlier, this result should be interpreted with much caution given that only a few subjects were responsible for the observed interaction.

The differences between the results for both versions of the stop task may be accounted for by differences in the characteristics of the two tasks (Band, 1997; Logan, 1994). First, in contrast to the stop task with fixed intervals, the tracking procedure does not depend on the assumption that the inhibition process has a constant latency. Second, in the stop task with tracking mechanism, SSRT is estimated around

a central delay where the inhibition rate is .5, whereas in the stop task with fixed intervals, SSRT is estimated at different inhibition rates. Third, the tracking algorithm corrects for the tendency to wait for the stop signal. How these task differences may affect performance is not clear. Besides differences in the methods for estimating SSRT, it should be noted that the small number of participants increases the risk of obtaining chance findings. Therefore, future research will be needed to address the issue of possible differences between the two methods of assessing inhibitory control.

The magnitude of the effects differed for the two behavior dimensions. Results for Internalizing Behavior were less conclusive than for Externalizing Behavior. This might be attributed to the reliability of the aggregate measures. Whereas the reliability of the Externalizing Behavior composite score was found to be satisfactory (Cronbach's  $\alpha = .91$ ), the reliability of the Internalizing Behavior composite score was found to be moderate (Cronbach's  $\alpha = .63$ ). The moderate reliability for the Internalizing Behavior composite may be related to the small number of scales that it incorporates.

The present findings are partially in accord with the results of previous studies. The results from this dimensional study show what has already been demonstrated with a categorical approach (see for a review Oosterlaan et al., 1998); children who show relatively high levels of externalizing behavior have impaired inhibitory control. What previous studies using a categorical approach have not done, is to show a link between internalizing behavior and inhibition (Daugherty et al., 1993; Oosterlaan & Sergeant, 1996, 1998a, 1998b). From the present study, however, using a dimensional approach, our hypothesis of enhanced inhibitory control in children with relatively high levels of internalizing behavior was supported. This finding corroborates Quay's (1988a, 1988b, 1993, 1997) theory of BIS and BAS functioning in child psychopathology.

A limitation of this type of study in which a dimensional analysis was conducted, is that no causal relations can be inferred. In order to make causal attributions one would have to do a

longitudinal study into the development of inhibition. A forte of this study is that, even in a small sample of normal children, three out of four regression analyses supported a link between dimensions of psychopathology and inhibitory control.

The stop task is purported to measure one form of inhibition, i.e., behavioral inhibition, and in particular the ability to inhibit a prepotent response. Several other forms of inhibition have been distinguished. Nigg (2000) distinguishes between interference control, cognitive inhibition, behavioral inhibition, and oculomotor inhibition. A similar distinction has been suggested by Barkley (1997). It remains to be seen whether the current findings generalize to other definitions of inhibition, not targeted by the stop task.

A potentially important line of research would be to investigate the clinical implications of the results of this study. Ultimately, the concept of inhibition deficits may prove to be a useful aid in identifying children with internalizing and externalizing behavior, even before these behavioral tendencies have surfaced.

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