Task Complexity Enhances Response Inhibition Deficits in Childhood and Adolescent Attention-Deficit/Hyperactivity Disorder: A Meta-Regression Analysis

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Background: The ability to inhibit motor responses, as assessed by the stop-signal reaction time (SSRT), is impaired in children and adolescents with attention-deficit/hyperactivity disorder (ADHD). However, the between-study variation in effect sizes is large. The aim of this study was to investigate whether this variability can be explained by between-study variation in Go task complexity.

Method: Forty-one studies comparing children or adolescents diagnosed with ADHD to normal control subjects were incorporated in a random-effects meta-regression analysis. The independent variables were a global index of Go task complexity (i.e., mean reaction time in control subjects [RTc]) and a more specific index (i.e., spatial compatibility of the stimulus-response mapping). The dependent variable was the SSRT difference between ADHD and control subjects.

Results: The SSRT difference increased significantly with increasing RTc. Moreover, the SSRT difference was significantly increased in studies that employed a noncompatible, that is, arbitrary, mapping compared with studies that incorporated a spatially compatible stimulus-response mapping.

Conclusions: These results indicate that inhibitory dysfunction in children and adolescents with ADHD varies with task complexity: inhibitory dysfunction in ADHD is most pronounced for spatially noncompatible responses. Explanations in terms of inhibition and working memory deficits and a tentative neurobiological explanation are briefly discussed.

Key Words: Attention-deficit/hyperactivity disorder, meta-regression, response inhibition, spatial compatibility of stimulus-response mappings, stop-signal paradigm

One of the key symptoms of attention-deficit/hyperactivity disorder (ADHD) is the inability to inhibit motor responses when signaled to do so (1–5). Many studies used the well-established stop-signal paradigm to obtain an index of inhibitory efficiency (6–7). The stop-signal task usually requires participants to perform a Go task that involves a speeded choice response—for example, to issue a right-hand button press to an X and a left-hand press to an O. Occasionally and unpredictably, a stop signal is presented shortly after the Go signal, instructing the participant to withhold the response activated by the Go signal. Varying the onset of the stop signal allows for the calculation of the latency of the covert stop process, or the stop-signal reaction time (SSRT), as an index of inhibitory control (7).

Children diagnosed with ADHD typically show a prolonged stop-signal RT compared with healthy age-matched control subjects, as shown in three meta-analyses (8–10). Although the reported average effect sizes deviate significantly from zero in all three meta-analyses, the variation across clinical studies is large: the reported difference between SSRT in ADHD versus control subjects varies between 0 and 190 msec. Transforming these differences to standardized effect sizes (Hedges G) yields effect sizes varying between 0 and 1.3. This broad range is remarkable, given the fact that in the behavioral sciences, a Hedges G effect size of .2 is considered small and .8 as large (11). The central aim of this study was therefore to identify task-related factors that may have contributed to this large variation in effect sizes between studies.

The Go tasks used in the stop-signal paradigm can be characterized by the degree of spatial compatibility of the stimulus-response mapping, which may be spatially compatible, spatially noncompatible, or spatially incompatible (12). An example of a spatially compatible task is a right-hand button press when an arrow points to the right and a left-hand button press if an arrow points to the left. A spatially noncompatible task may require a right-hand button press to an X and a left-hand button press to an O. Note that in this case, the mapping between stimulus and response is arbitrary. A spatially incompatible task may require a right-hand button press after a left-pointing arrow and a left-hand button press after a right-pointing arrow.

From nonclinical studies, it is well known that responses are slower on tasks that are spatially less compatible than on compatible tasks (12–14). In addition, several nonclinical studies have shown diminished inhibitory control over responses that are spatially less compatible than compatible mappings (15–21). ADHD studies indicated that children with ADHD respond disproportionally slower in tasks that are spatially less compatible (22–24; meta-analysis in 25).

In sum, in nonclinical studies, it has been shown that spatial compatibility affects both response speed and inhibitory control. In ADHD studies, it has been shown that spatial compatibility has a disproportional effect on response speed. This leads to the conjecture that spatial compatibility of the stimulus-response mapping may also have a disproportional effect on inhibitory control in children diagnosed with ADHD. More specifically, we hypothesized that spatial compatibility may be an important factor that explains the large variation in effect sizes between

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Table 1. Characteristics of Studies Incorporated in the Meta-Regression Analysis

				ADHD Subjects					Control Subjects						
Study	Method	Task[a]	Cmp[b]	N	RT	SD(RT)	SSRT	SD(SSRT)	N	RT	SD(RT)	SSRT	SD(SSRT)	SSRTa-SSRTc	Var(SSRTa-SSRTc)
Bedard (2003) (26)	Tracking	Stop-sel	−1	59	567	158	524	235	59	587	223	403	187	121	1529
Bitsakou (2008) (27)	Tracking	Stop	−1	54	615	118	286	108	29	660	140	254	98	32	580
Bitsakou (2008) (27)	Tracking	Stop	−1	23	546	138	300	153	21	559	133	201	57	99	1258
Chhabildas (2001) (28)	Tracking	Stop	−1	33	—	—	341	131	82	—	—	258	85	83	427
Daugherty (1993) (29)	Variable	Stop	−1	11	739	—	153	—	15	702	—	148	—	5	2826[c]
Dimoska (2003) (30)	Tracking	Stop	−1	13	724	69	360	61	13	645	112	260	88	100	882
Geurts (2004) (31)	Variable	Change	1	54	498	129	321	96	41	487	101	237	72	84	321
Jennings (1997) (32)	Fixed	Stop	3	12	527	—	348	—	26	515	—	352	—	−4	2184[c]
Johnstone (2007) (33)	Tracking	Stop	−1	13	743	117	480	164	13	667	162	541	88	−61	2665
Konrad (2000) (34)	Tracking	Stop	1	31	612	59	431	77	26	572	69	357	76	74	414
Konrad (2000) (35)	Tracking	Stop	1	10	593	30	431	62	10	572	64	351	70	80	874
Kuntsi (2001) (36)	Variable	Stop	1	51	527	96	239	81	118	476	102	222	68	17	146
Liotti (2007) (37)	Variable	Stop	−1	16	840	176	283	163	30	966	147	210	102	73	1525
Manassis (2000) (38)	Tracking	Stop	−1	15	672	139	288	157	16	567	105	237	157	51	3184
McInerney (2003) (39)	Tracking	Stop	−1	30	—	—	364	100	30			289	74	75	516
Nigg (1999) (40)	Tracking	Stop	−1	25	714	98	405	156	25	652	148	295	84	110	1256
Nigg (2002) (41)	Tracking	Stop	−1	64	719	105	399	170	41	654	129	298	83	101	814
Nigg (2007) (42)	Tracking	Stop	−1	134	—	—	418	156	72	—	—	322	108	96	425
Oosterlaan (1996) (43)	Variable	Stop	1	15	428	71	256	63	17	352	58	224	33	32	305
Oosterlaan (1998) (44)	Variable	Stop	1	14	420	80	247	139	21	330	50	192	69	55	1250
Overtoom (2002) (45)	Fixed	Stop	1	16	598	161	454	280	16	508	104	262	91	192	5418
Pliszka (1997) (46)	Variable	Stop	−1	13	839	108	329	90	14	731	65	221	67	108	923
Pliszka (1997) (46)	Variable	Stop	−1	25	—	—	288	163	31	—	—	176	59	112	993
Pliszka (2000) (47)	Variable	Stop	−1	10	625	140	428	155	10	679	114	337	73	91	2935
Pliszka (2006) (48)	Variable	Stop	−1	8	1040	290	719	124	15	1175	120	644	108	75	2473
Purvis (2000) (49)	Tracking	Stop	−1	17	658	105	308	132	17	534	89	265	86	43	1460
Rubia (1998) (50)	Variable	Stop	1	11	603	82	330	81	11	602	83	260	26	70	658
Rubia (2001) (51)	Fixed	Stop 1	2	16	590	109	271	113	23	611	93	229	38	42	640
Rubia (2005) (52)	Tracking	Stop	1	16	809	121	210	316	21	758	161	255	283	−45	9752
Rubia (2007) (53)	Tracking	Stop	1	32	—	—	279	105	34	—	—	214	75	65	500
Rucklidge (2002) (54)	Tracking	Stop	−1	35	440	107	216	122	37	404	105	152	52	64	479
Schachar (1995) (56)	Variable	Stop	−1	14	841	202	472	259	22	719	137	355	94	117	3636
Schachar (2000) (55)	Tracking	Stop	−1	72	664	133	332	149	33	579	108	264	76	68	756
Schachar (2004) (57)	Tracking	Stop	−1	151	635	135	314	168	41	578	138	234	98	80	754
Schachar (2007) (58)	Tracking	Stop	−1	78	620	109	326	163	50	612	150	255	109	71	685
Scheres (2001) (59)	Tracking	Stop	1	24	456	91	251	128	41	404	72	222	95	29	774
Slusarek (2001) (60)	Tracking	Stop	1	33	569	172	297	139	33	584	156	251	116	46	993
Solanto (2001) (61)	Variable	Stop	−1	77	764	186	436	281	29	769	119	290	104	146	2877
Stevens (2002) (62)	Tracking	Stop	−1	76	506	—	343	—	76	526	—	296	—	47	472[c]
Walcott (2004) (63)	—	Stop	−1	26	—	—	434	105	23	—	—	311	90	123	791
Willcutt (2005) (64)	Tracking	Stop	−1	113	672	121	340	125	151	660	118	281	115	59	220

RT, mean reaction time to go signal; SD(RT), within-group standard deviation of RT; SSRT, stop-signal reaction time; SD(SSRT), within-group standard deviation of SSRT; Var(SSRTa-SSRTc), estimated variance of SSRT difference between ADHD and control subjects (this estimator requires that the variance of SSRT is reported [66] p. 331).

[a]Stop, stop task; Stop-sel, stop task, but only inhibit responses after one type of stop stimulus; Change, change task; Stop 1, Go task is not a two-choice task but only requires a single response.

[b]Cmp: −1, spatially noncompatible; 1, spatially compatible; 2, only single response required; 3, spatially compatible movement of mouse.

[c]Three studies did not report SD(SSRT); in these cases, the average of other studies was used.

stop-signal studies that compared children or adolescents with ADHD to healthy control subjects.

Methods and Materials

Inclusion Criteria for Studies

All studies reported in previous meta-analyses (8–10) were considered as possible candidates for the present meta-regression analysis. In addition, using Web of Science, we searched the literature between 1995 and 2008 with key words *ADHD* or *attention-deficit/hyperactivity disorder* and *stop task* or *stop-signal task*. We included only studies that satisfied the following criteria: 1) the study should concern children or adolescents (or both) up to 18 years of age,[1] 2) the study should address a comparison between ADHD and normal control subjects; 3) the study should report the SSRT. This resulted in 41 studies for further analysis (26–64; see Table 1).

Some studies reported multiple experimental conditions or groups. One study compared nonreward and reward conditions (35). Because there was a significant interaction of this manipu-

[1]We included only child and adolescent studies because there are indications that ADHD inhibition deficits may differ between children/adolescents and adults (9).

lation with group (ADHD vs. controls), we incorporated only the nonreward condition, matching most other studies. Reinforcement was manipulated in two studies (44,62), but no interaction with group was found, and therefore results were pooled across reinforcement conditions. The duration of each trial was manipulated in one study (59), but results were averaged across duration conditions because there was no interaction with group. Study (46) consisted of two substudies, and differences between these studies were not tested; therefore, we incorporated the two studies separately. In one study (27), both children and adolescents were investigated; because there were effects of age group, we incorporated the two studies separately.

Most studies used the variable or tracking stop-signal paradigm, except for three studies (32,45,51) that reported a fixed stop-signal paradigm. The fixed stop-signal paradigm uses only one stop-signal delay, the variable paradigm has multiple delays, and the tracking paradigm dynamically sets the stop delay in an online fashion. Because the fixed method may yield less reliable results than the variable and tracking paradigms (65), we performed the meta-regression twice: first including all studies, and again excluding the fixed-delay studies. In addition, two studies, one with compatible and one with noncompatible mapping (33,52), reported negative effect sizes, indicating that participants with ADHD actually performed better than normal control subjects. To check whether these two outliers substantially affected the results, we performed a third analysis without them.

Meta-Regression

Meta-regression offers the opportunity to determine whether continuous or discrete study characteristics influence effect sizes. More specifically, effects sizes (the dependent variable) are regressed on study characteristics (the independent variables), and the resulting coefficients and associated tests provide an indication of the influence of study characteristics. In a random-effects meta-regression, two types of variation are taken into account: within-study variation and between-study variation. In a fixed-effects meta-regression, it is assumed that between-study variation is zero, and only within-study variation is incorporated. Consequently, a fixed-effects analysis is more powerful but, unfortunately, also less reliable if between-study variation is present (66,67). Therefore, the present analyses were performed with a random-effects meta-regression (MiMa software) (68). A random effects meta-regression yields an estimator and test of between-study variation (*QE* statistic), as well as estimates and tests of effects of study characteristics. All test results are two-tailed.

Choice of Dependent Variable

The effect size was the SSRT difference between ADHD and control subjects: SSRTa-SSRTc (69).[2] This effect size is shown in the SSRTa-SSRTc column in Table 1. A random effects meta-regression requires that the variance of each effect size be incorporated into the analysis. This variance of the effect size, which is a function of within study variance (cf. 66), is tabulated in the var(SSRTa-SSRTc) column in Table 1.

Choice of Independent Variables

The mean reaction time to the Go signal in control subjects (RTc) was taken as a global index of Go task complexity (cf. 8,41). RTc was incorporated as a continuous independent variable in the meta-regression. The other nominal independent variable was an experimentally set and therefore a more specific, index of Go task complexity. It referred to spatial compatibility of the stimulus-response mapping in the Go task. All studies that required a spatially compatible response were coded as 1. One study (32) required the movement of a mouse toward a target, and one study (51) required only a single response. These were also coded as compatible responses. All remaining studies required the translation of a nonspatial stimulus (e.g., X and O) into a spatial response. These studies were coded as noncompatible responses: −1. Note that none of the studies employed an incompatible mapping.

Results

Test of Hypotheses

A meta-regression without independent variables indicated that the average SSRT difference deviated significantly from zero ($b = 67.37$, $p < .001$) and that there was significant variation between studies ($QE = 63.47$, $df = 40$, $p = .01$).

Study characteristics and results are given in Table 1. As can be seen in the left panel of Figure 1, there is a positive relationship between the SSRT difference and task complexity as assessed by RTc. That is, the SSRT difference increased with increasing task complexity. This was supported by the meta-regression results, that is, the RTc effect showed a trend ($b = .08$, $p = .06$). Another indication that RTc is important is based on the observation that incorporation of RTc as independent variable reduced the significant variation between studies ($QE = 44.90$ $df = 33$, $p = .08$).

In Figure 1, it can also be seen that large SSRT differences are associated with noncompatible responses, whereas small SSRT differences are associated with spatially compatible responses. This compatibility effect was found to be significant in the meta-regression ($b = -13.34$, $p < .01$). Incorporation of the compatibility effect as independent variable again reduced between-study variation ($QE = 51.32$, $df = 39$, $p = .09$).

A reanalysis excluding the three fixed stop-signal studies yielded comparable results. The RTc trend remained ($b = .08$, $p = .06$), as did the compatibility effect ($b = -13.05$ $p = .01$). A reanalysis excluding also the two studies with negative SSRT differences did not remove effects (cf. Figure 1, right-hand panel); on the contrary, the effects became even stronger (RTc effect: $b = .09$, $p = .03$; compatibility effect ($b = -13.76$ $p < .01$).

Tests of Potential Confounds

The aforementioned results indicate that task complexity affects SSRT differences between ADHD and normal control subjects, but this effect may be due to potential confounds. More specifically, it might be argued that these task-complexity effects are due to a coupling with sample characteristics, such as age, medication status, the proportion of females in the ADHD sample, or ADHD types in each study. If such a coupling would exist, then these confounds, listed in Table 2, would have a significant effect on the SSRT difference. Moreover, adding a

[2]Two types of effect sizes may be considered (66). One option is a difference between means, SSRTa-SSRTc. Another option is Hedges G, a difference between means divided by its standard deviation. The advantage of Hedges G is that it transforms different dependent variables into a similar scale. However, a disadvantage is that effect sizes depend not only on the key variable of interest, the SSRT difference, but also on its standard deviation. This may distort the relationship between study characteristics and SSRT differences (69). Because all studies used the same dependent variable, SSRT, there is no need to use Hedges G, and therefore we were able to use mean differences.

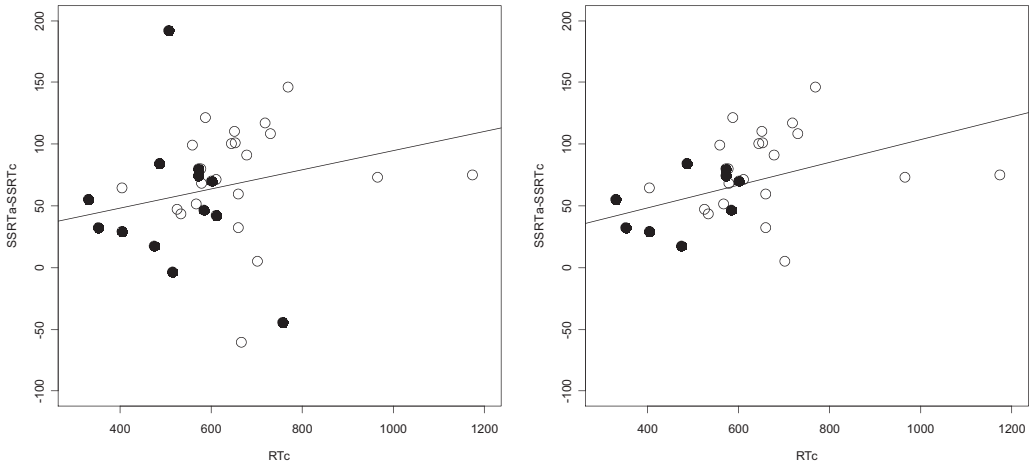

Figure 1. Stop-signal reaction time differences between subjects with attention-deficit/hyperactivity disorder (ADHD) and control subjects as a function of mean reaction time in controls (RTc) for studies that employed a spatially compatible (filled circles) versus a noncompatible mapping (open circles). The regression line depicts the effect of RTc obtained from the meta-regression for all studies (left panel) and for only those studies that incorporated the variable or tracking procedure and did not report negative effect sizes (right panel).

potentially confounding variable to the analysis would then remove the task complexity effect.

We therefore tested whether a potentially confounding variable affected the SSRT difference and, if so, whether it reduced the task complexity effect. To promote conciseness, all tests of confounding variables concern the reduced data set in which we omitted fixed studies and studies with negative effect sizes. This data set is not diluted by potential artefacts and therefore yields the highest power to detect confounding variables. In addition, also for reasons of conciseness, we only report results concerning the compatibility effect; tests of the MRTc effect gave rise to similar conclusions.

Average age and medication status (medication free vs. off medication for at least 18 hours) were unrelated to the SSRT difference (respectively $p = .85$ and $p = .11$). Effect sizes decreased if the percentage of females in the ADHD sample increased ($b = -73.28$, $p = .04$). A meta-regression with both percentage of females and compatibility yielded a significant compatibility effect ($b = -15.65$, $p < .001$). This indicates that the percentage of females in the ADHD sample is not confounded with task complexity.

The samples consisted of various ADHD types (cf. Table 2): hyperactive, inattentive, combined, combined plus conduct disorder, or a mixture of any of these four diagnoses. We tested the potential confounding variable: presence of conduct disorder. This effect was found to be significant: studies that included (some) children or adolescents with conduct disorder yielded higher SSRT differences than studies without conduct disorder ($b = 12.60$, $p = .04$). If both diagnosis and compatibility were included in the meta-regression analysis, the compatibility effect remained significant ($b = -15.49$, $p < .001$). This shows that diagnosis is not confounded with task complexity.

It might also be argued that the compatibility effects are related to other task characteristics (Table 2). We first investigated the effect of the attractiveness of a Go task stimulus, presuming that a picture (i.e., a plane) is more attractive than a symbol (i.e., a square or a character). A meta-regression analysis indicated, however, a nonsignificant effect of attractiveness on the SSRT difference ($p = .11$). It also might be argued that RTc does not reflect task difficulty but instead the speed-accuracy trade-off in a particular study. In this case, the percentage of incorrect responses would also affect the SSRT difference. However, this was not found to be the case ($p = .12$). In addition, the percentage of stop trials and the number of test trials failed to influence the SSRT difference (respectively, $p = .53$, $p = .54$). There was a significant effect of the number of learning trials, with the SSRT difference decreased with an increasing number of learning trials ($b = -.54$, $p < .01$). However, a meta-regression with both the number of learning trials and the compatibility effect still yielded a significant compatibility effect ($b = -15.3$, $p = .02$), indicating that the number of learning trials is not a confounding variable.

In sum, although we did find significant effects of the percentage of female participants in the ADHD sample, the presence of conduct disorder in the ADHD sample, and the number of learning trials, none of these variables acted as a confounder of the compatibility effect.

Discussion

Several studies have shown that the reaction time of children with ADHD, as compared with normal control subjects, is more affected in spatial incompatible (22–24) and spatial noncompatible (25) tasks. This study shows that inhibitory dysfunction of children with ADHD, compared with normal control subjects, is also more affected in spatial noncompatible tasks.

Two interpretations, not necessary mutually exclusive, may underlie the effect of noncompatibility on inhibitory dysfunction. One interpretation explains the effect in terms of an interaction between two inhibitory mechanisms. An arbitrary mapping may engender greater competition for response selection. That is, if the participant is confronted with a stimulus that requires an arbitrary mapping to a response, then there is activation of both response options that should be inhibited until the participant has matched the stimulus to the required response. This inhibition of nonspecific response activation might interact with the inhibitory process required for stopping. Note that there is less need for this initial suppression when applying spatially compatible mapping rules because here the translation of a stimulus to response occurs faster.

A second interpretation is that although storage of a complex stimulus-response mapping in working memory and inhibition

Table 2. Potential Confounds

	Potential Sample Confounds				Potential Task Confounds				
Study	Age	ADHD %F	Diagnosis[a]	Medic[b]	Stimulus[c]	No. Learning	No. Test	% Stop	% Error C
Bedard (2003) (26)	8.5	.20	A/H/(C+CD)	—	Character (X/O)	32	192	20	7.7
Bitsakou (2008) (27)	10.7	.19	C	>18	Character (X/O)	64	128	25	—
Bitsakou (2008) (27)	14.4	.17	C	>18	Character (X/O)	64	128	25	—
Chhabildas (2001) (28)	11.1	.27	C	>18	Character (X/O)	—	—	—	—
Daugherty (1993) (29)	11.2	—	C+CD	—	Character (X/O)	96	432	25	2.4
Dimoska (2003) (30)	9.8	—	A/C	>18	Character (T/O)	24	240	30	5.9
Geurts (2004) (31)	9.2	.00	A/H/(C+CD)	>18	Picture (position plane)	64	256	25	—
Jennings (1997) (32)	9.8	.00	C	>18	Picture (position ice cream cart)	>25	200	30	—
Johnstone (2007) (33)	11.7	.23	C	>18	Picture (apple/lion)	24	240	30	10.7
Konrad (2000) (34)	10.4	.10	A/H/C	off	Picture (position ufo)	80	320	25	—
Konrad (2000) (35)	10.5	.20	A/H/C	off	Picture (position ufo)	80	320	25	—
Kuntsi (2001) (36)	8.9	.53	H	off	Picture (position plane)	128	256	25	2.9
Liotti (2007) (37)	12.6	.31	C	off	Character (A/B)	192	960	25	13
Manassis (2000) (38)	10.1	.27	C	—	Character (X/O)	64	256	25	—
McInerney (2003) (39)	10.1	.10	C	>18	Character (X/O)	—	128	25	—
Nigg (1999) (40)	8.9	.32	C+CD	—	Character (X/O)	64	256	25	7
Nigg (2002) (41)	15.0	.41	A/(C+CD)	>18	Character (X/O)	64	256	25	—
Nigg (2007) (42)	9.5	.31	A/C	>18	Character (X/O)	64	256	25	—
Oosterlaan (1996) (43)	9.0	.13	C	>18	Symbol (position square)	64	256	25	4.8
Oosterlaan (1998) (44)	10.1	.14	C	>18	Picture (position plane)	64	256	25	5.5
Overtoom (2002) (45)	10.4	.00	C+CD	>18	Picture (direction feather clown)	360	600	40	4.9
Pliszka (1997) (46)	7.4	.08	C+CD	FMTT	Symbol(light green/red)	48	432	25	3.8
Pliszka (1997) (46)	—	.15	C+CD	FMTT	Symbol(light green/red)	48	432	25	—
Pliszka (2000) (47)	11.2	.00	C	>18	Character (A/B)	—	1440	25	4.0
Pliszka (2006) (48)	13.1	.38	C	off	Character (A/B)	—	480	25	6.0
Purvis (2000) (49)	9.3	.06	C	>18	Character (X/O)	—	156	25	5.1
Rubia (1998) (50)	9.2	.00	C+CD	FMTT	Picture (position plane)	—	200	30	3.5
Rubia (2001) (51)	15.4	—	C	>18	Picture (plane)	90	180	30	—
Rubia (2005) (52)	13.5	.0	C+CD	>18	Symbol (direction arrow)	—	196	20	
Rubia (2007) (53)	11.1	.06	C+CD	>18	Picture (direction plane)	—	178	27	—
Rucklidge (2002) (54)	15.1	.43	C	>18	Character (X/O)	—	—	25	3.5
Schachar (1995) (56)	9.0	—	C	>18	Character (X/O)	72–216	288	—	—
Schachar (2000) (55)	9.2	.20	C	>18	Character (X/O)	64	256	25	—
Schachar (2004) (57)	8.8	.23	A/H/C	>18	Character (X/O)	—	96	25	5.7
Schachar (2007) (58)	9.8	.21	A/H/(C+CD)	>18	Character (X/O)	—	128	25	3.8
Scheres (2001) (59)	10.2	.25	A/H/C	>18	Picture (direction plane)	128	192	25	6.3
Slusarek (2001) (60)	9.3	—	C	—	Symbol (position cross)	30	192	—	8.0
Solanto (2001) (61)	8.6	.14	C/(C+CD)	FMTT	Character (X/O)	32	240	33	—
Stevens (2002) (62)	10.0	.24	C	>18	Character (X/O)	—	320	25	—
Walcott (2004) (63)	9.2	.00	C	>18	Character (X/O)	—	256	—	—
Willcutt (2005) (64)	11.4	.35	A/C	>18	Character (X/O)	—	—	—	—

ADHD %F, percentage of female subjects in attention-deficit/hyperactivity disorder (ADHD) sample; Age, average age; No. Learning, number of learning trials; No. test, number of test trials; % stop, percentage of stop trials; % error C, commission error percentage in control subjects.

[a]Diagnosis was with *DSM-III*. A, inattentive; C, combined, C+CD: combined where some children were diagnosed with conduct disorder; H, hyperactive/impulsive. Studies without conduct disorder were coded as −1, with conduct disorder as +1.

[b]Medication (Medic): off, no medication; >18, if stimulants were used, then participants were asked to refrain from medication at least 18 (in general 24) hours before testing; FMTT, free of medication at time of testing. Off was coded as −1, >18 and FMTT were coded as +1.

[c]Stimuli were characters, pictures, or symbols. Characters and symbols were coded as unattractive stimuli (−1), and pictures were coded as attractive stimuli (+1).

are different processes, they both tap into the same control mechanism. This interpretation would gain plausibility 1) if working memory and inhibition require intactness of the same anatomic regions and 2) if children or adolescents with ADHD suffer from deficits in tasks that draw on working memory and on inhibition. The first requirement seems to be fulfilled, because both working memory and inhibition in the stop-signal task require intactness of the right inferior frontal gyrus (3,70,71). The second requirement is also met because ADHD is not only characterized by inhibition deficits but also by marked working memory impairments (1,2,72). It should be stressed again, however, that the two explanations just outlined are not mutually exclusive. The ADHD deficit in stopping noncompatible responses could be related to both impairments in working memory and interactions between manifestations of inhibitory control.

As noted earlier, recent studies indicate that the right inferior frontal gyrus function might function suboptimally in ADHD (3,71). Moreover, Chambers *et al.* (73,74) showed in a set of transcranial magnetic stimulation studies that the right inferior frontal gyrus is crucial for successful inhibition of responses to spatially incompatible (74) and spatially noncompatible (73)

stimuli but not for inhibition of responses to spatially compatible stimulus arrays (74). Therefore, our finding that inhibitory difficulties in ADHD are especially pronounced in spatially noncompatible tasks is in line with the observation that the right inferior frontal gyrus functions suboptimally in ADHD.

Obviously, our findings should be interpreted with caution. Meta-regression is a correlational technique, and therefore causal relationships cannot be inferred. However, we were able to show that none of the additionally investigated sample- or task-related variables acted as a confound. This does not imply that these variables do not explain variation between studies. In fact, it was found that studies with a higher percentage of females in the ADHD sample showed smaller SSRT differences, that studies incorporating children or adolescents with conduct disorder reported higher SSRT differences, and that studies with a larger number of learning trials reported smaller SSRT differences.

To conclude, this meta-regression analysis shows that the magnitude of ADHD inhibition deficits depends on the complexity of the Go task. More specifically, inhibitory deficits are more pronounced on tasks that require spatially noncompatible—that is, arbitrary—stimulus-response mappings than on tasks that require spatially compatible mappings. Therefore, if the stop task is used as an instrument to quantify inhibitory dysfunction in children with ADHD and if the primary interest of a study is to assess "pure" inhibition after a stop signal, independent of other inhibitory processes or working memory, it is advised to use a Go task with a compatible mapping. However, the Go task with a noncompatible mapping will yield a higher discriminating power. Another advantage of this noncompatible mapping is that it has larger real-life validity: in real life, most tasks require noncompatible stimulus-response mappings.

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