

Efficacy of Neurofeedback treatment in ADHD: The effects on Inattention, Impulsivity and Hyperactivity. A meta-analysis

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Neurofeedback in ADHD

- Lubar & Shouse (1976): First report on Neurofeedback in Hyperkinetic child.
 - Heinrich et al. (2004): First report on SCP Neurofeedback in ADHD.
 - Treatments investigated:
 - SMR / Theta training
 - Beta / Theta training
 - SCP training
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Neurofeedback for ADHD Efficacious?

- Monastra et al. (2005): ‘probably efficacious’.
 - Loo and Barkley (2005) “...*the promise of EEG Biofeedback as a legitimate treatment cannot be fulfilled without studies that are scientifically rigorous.*”
 - Holtmann and Stadtler (2006): “...*EEG Biofeedback has gained promising empirical support in recent years, but there is still a strong need for more empirically and methodologically sound evaluation studies.*”
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Meta-analysis

- Published in a peer-reviewed journal or be part of a PhD thesis.
- The designs had to comply with the following criteria:
 - Treated subjects should have a primary diagnosis of ADHD/ADD.
 - 1) Controlled between subject design studies who have used a passive (waiting list) or active (stimulant medication; biofeedback; cognitive training) control groups either randomized or not; or
 - 2) Prospective within subject design studies or
 - 3) Retrospective within subject design studies with a large enough sample to provide a reliable representation of daily practice (N>500).
 - The Neurofeedback treatment was provided in a standardized manner, and no more than two treatment protocols were used.

Meta-analysis

Pre- and post-assessment measures

- Hyperactivity: Assessed with a **DSM rating scale** such as Conners (CPRS-R); ADDES-Home, BASC, SNAP, FBB-HKS (parents) or DSM-IV Rating Scale (Lauth & Schlottko).
 - Inattention: Assessed with an **Inattention rating scale** such as FBB-HKS, Conners (CPRS-R, BASC, ADDES-Home, SNAP/Iowa-Conners) or DSM-IV Rating Scale (Lauth & Schlottko).
 - Impulsivity: **Commission errors** on a CPT such as a TOVA, IVA (auditory prudence measure) or Go-NoGo test.
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Table 1

This table shows an overview of all studies used in the meta-analysis. The study numbers correspond to the same numbers in the figures and the references.

A total of 476 subjects were included based on prospective controlled studies and 718 subjects for studies employing a pre- post-test design.

Study	Country	Conditions	n	Age	Measure	Instrument	NF Site	Treatment	Mean # Ses.	Notes
PROSPECTIVE CONTROLLED STUDIES										
40) Rossiter & La Vaque 1995	USA	Stimulant control group	ADHD: 23 Control: 23	12,9 12,9	Hyperactivity Impulsivity Inattention	BASC TOVA BASC	Cz or FCz-CPz	Beta/Theta 5/23 Medicated	20	
33) Monastra et al. 2002	USA	Control group	ADHD: 51 Control: 49	10 10	Hyperactivity Impulsivity Inattention	ADDES TOVA ADDES	CPz and Cz	Beta/Theta Medicated	43	Only included subjects with increased theta/beta ratio Less cortical slowing
27) Fuchs et al. 2003	USA	Stimulant control group	ADHD: 22 Control: 11	9,8 9,6	Impulsivity	TOVA	C3 or C4	Beta/Theta Unmedicated	36	
7) Heinrich et al. 2004	DE	Waiting list control	ADHD: 13 Control: 9	11,1 10,5	Hyperactivity Impulsivity Inattention	FBB-HKS CPT FBB-HKS	Cz	SCP 8/13 Medicated	25	↑CNV ERP
28) Rossiter 2004	USA	Stimulant control group	ADHD: 31 Control: 31	16,6 16,7	Hyperactivity Impulsivity Inattention	BASC TOVA BASC	C3 or C8	Beta/Theta 6/31 Medicated	50	
35) Levesque et al. 2006	CA	RCT Waiting list control	ADHD: 15 Control: 5	10,2 10,2	Hyperactivity Impulsivity Inattention	CPRS-R IVA CPRS-R	Cz	Beta/Theta Unmedicated	40	fMRI showed activation of the right ACCd, left caudate and left substantia nigra during Counting Stroop test
29) Bakhshayesh, 2007	DE	RCT Control group EMG Biofeedback	ADHD: 18 Control: 17	9,61 9,06	Hyperactivity Impulsivity	FBB-HKS CPT Commissions	FCz-CPz	Beta/Theta 4/18 Medicated	30	
18) Drechsler, 2007	CH	Group therapy control group	ADHD: 17 Control: 13	10,5 11,2	Inattention Hyperactivity Impulsivity Inattention	FBB-HKS FBB-HKS TAP: Go-NoGo FBB-HKS	Cz	SCP 6/17 Medicated	30	Doehnert (2008): Post-QEEG: Theta decreased at Oz
10) Gevensleben et al. 2009	DE	RCT Attention training control group	ADHD: 59 Control: 35	9,1 9,4	Hyperactivity Inattention	FBB-HKS FBB-HKS	Cz	SCP and Beta/Theta Unmedicated	36	
17) Holtmann et al. 2009	DE	RCT Captain's Log control group	ADHD: 20 Control: 14	10,3 10,2	Hyperactivity Impulsivity Inattention	FBB-HKS Go-NoGo FBB-HKS	Cz	Beta/Theta 27/34 Medicated	20	Normalization of Frontal No-Go N2 ERP
		Total N:	476							
PROSPECTIVE PRE- / POST-DESIGN STUDIES										
31) Kropotov et al. 2005	Russia	Pre-/post-design	ADHD: 18	11,4	Hyperactivity Impulsivity Inattention	SNAP-4 Go-NoGo SNAP-4	C3-Fz or C4-Pz	Beta (C3) SMR (C4) Unmedicated	17	Normalization of ERPs for good-performers
32) Xiong et al. 2005	China	Pre-/post-design	ADHD: 60	>6	Omissions	SNAP-4 IVA	?	Beta/Theta Unmedicated	40	
30) Strehl et al. 2006	DE	Pre-/post-design Randomized to SCP or Beta/Theta	ADHD: 23	9,3	Hyperactivity Impulsivity Inattention	DSM-IV RS TAP: Go-NoGo DSM-IV RS	Cz	SCP 5/23 Medicated	30	
11) Leins et al. 2007	DE	Pre-/post-design Randomized to SCP or Beta/Theta	ADHD: 19	9,2	Hyperactivity Impulsivity Inattention	DSM-IV RS TAP: Go-NoGo DSM-IV RS	C3f and C4f	Beta/Theta 1/19 Medicated	30	
RETROSPECTIVE PRE-/POST-DESIGN STUDY										
34) Kaiser & Othmer, 2000	USA	Multisite naturalistic pre-/postdesign	ADHD: 530*	17,3	Impulsivity	TOVA	C3, C4	Beta/Theta Unmedicated		
		Total N:	718							

SCP = Slow Cortical Potentials; SMR = Sensorimotor EEG Rhythm; RCT = Randomized Controlled Trial; DSM-IV RS = DSM-IV Rating Scale (Lauth & Schlotke). * The original Kaiser & Othmer sample consisted of 1089 subjects, however Means and SDs were only available for N=530 (Kaiser, personal communication.)

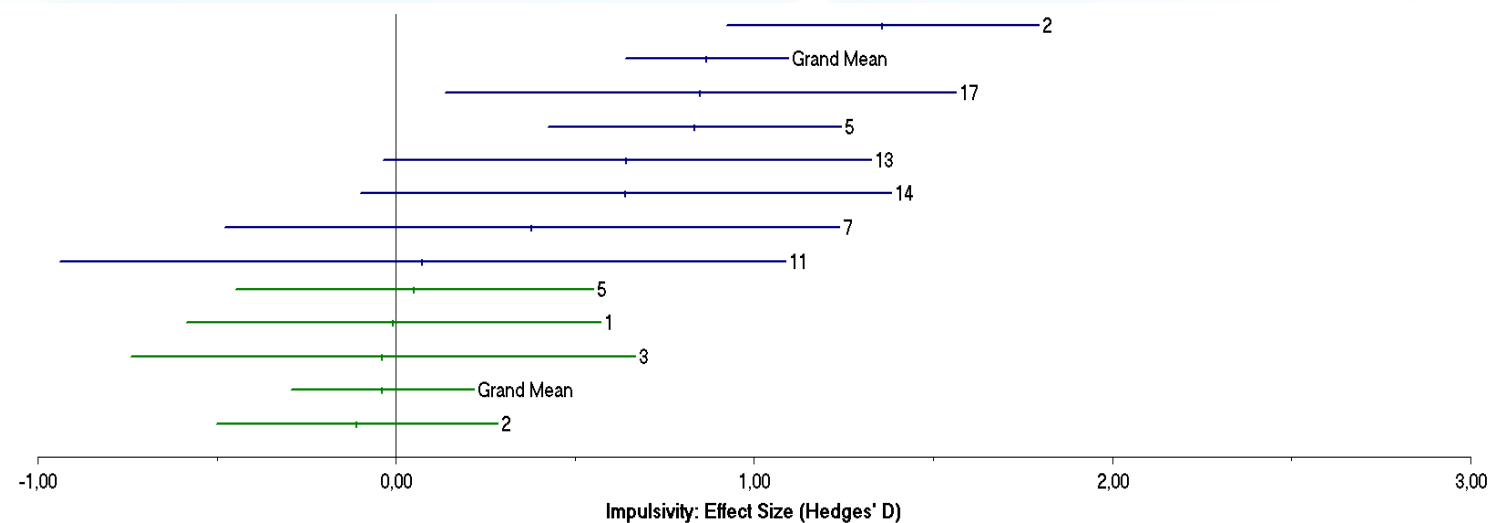
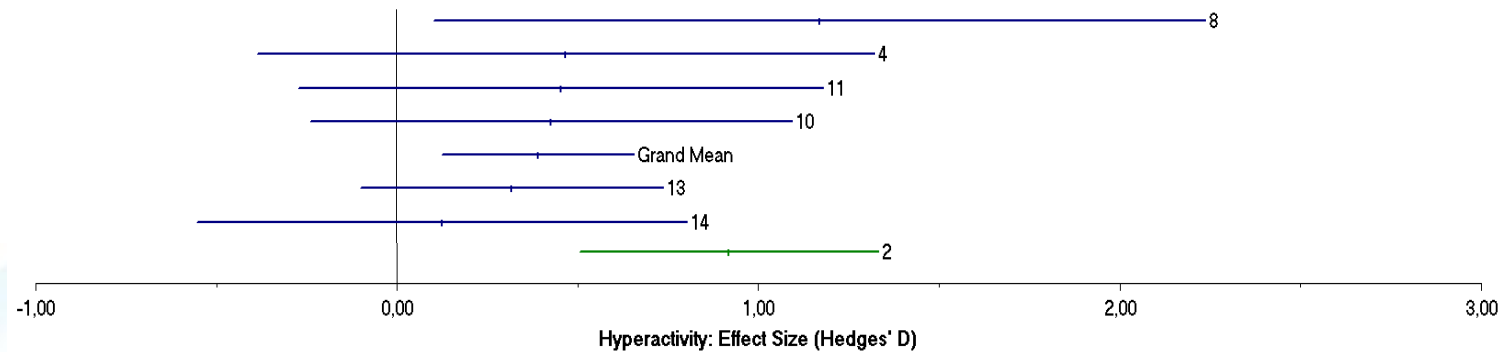
Results

- 15 studies included, total N=1194
 - 7 studies from Germany; 4 from the USA
 - 6/15 used randomization
 - 3 used 'credible' sham control (EMG Biofeedback or Attention Training i.e. Captian's Log)
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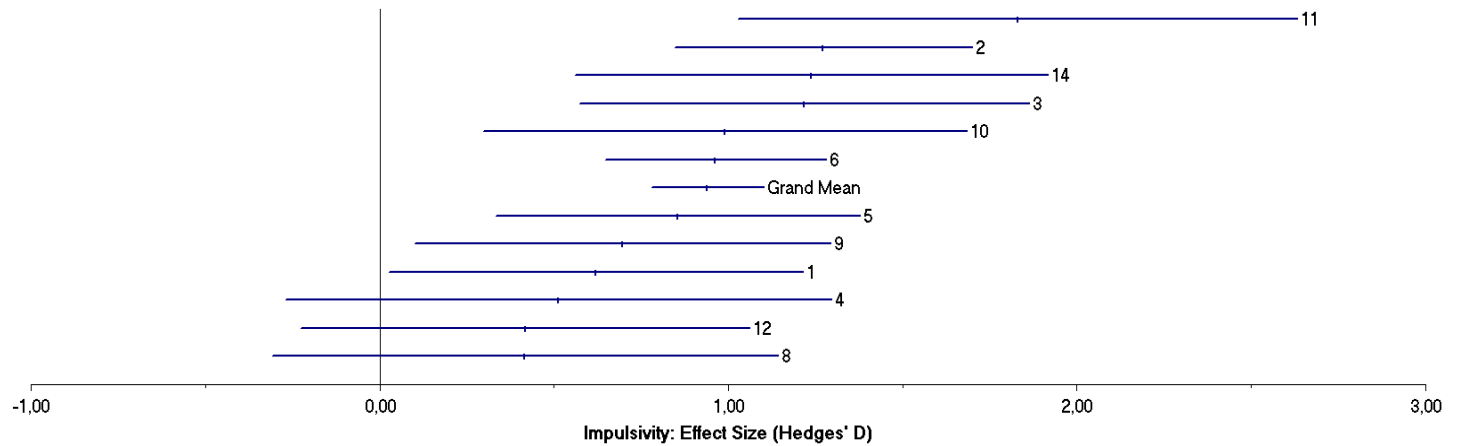
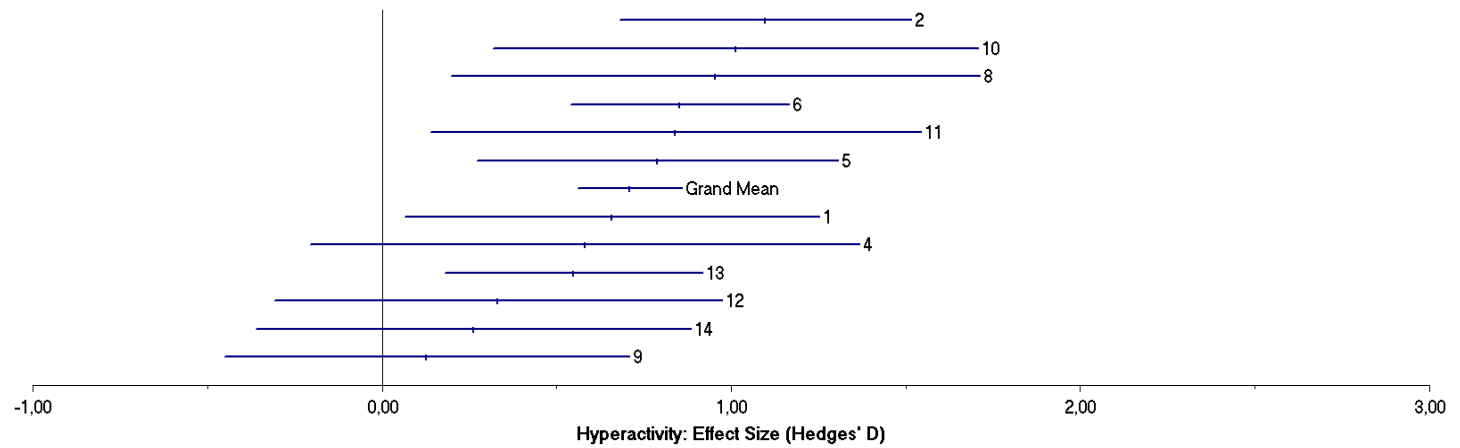
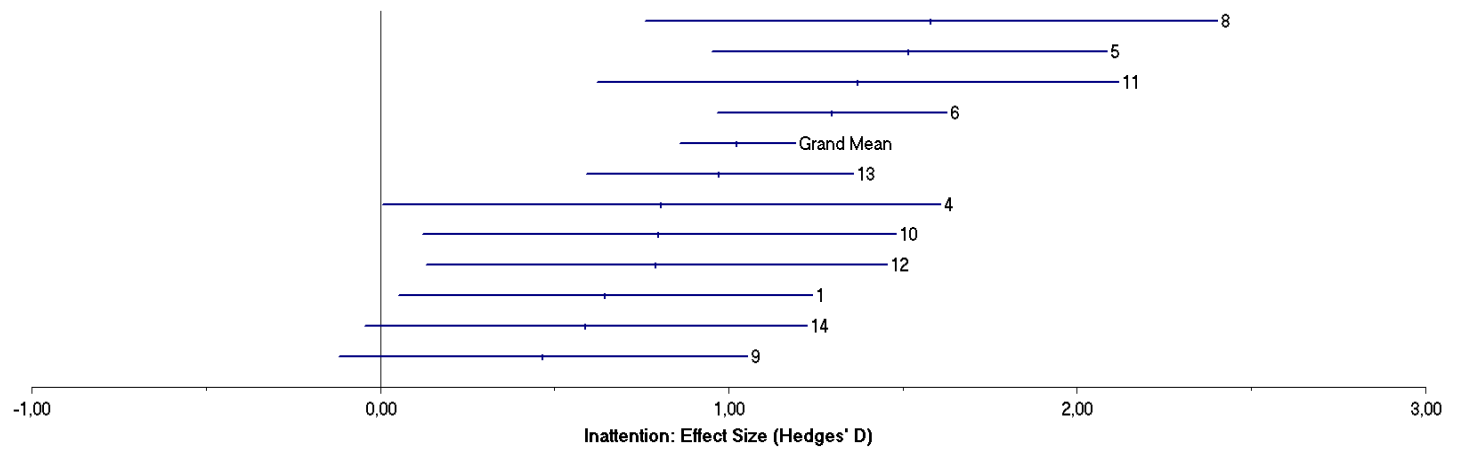
Effect sizes
of
prospective
controlled
studies with
95% CI

Blue lines:
NF vs.
Passive/
semi-active
control
group

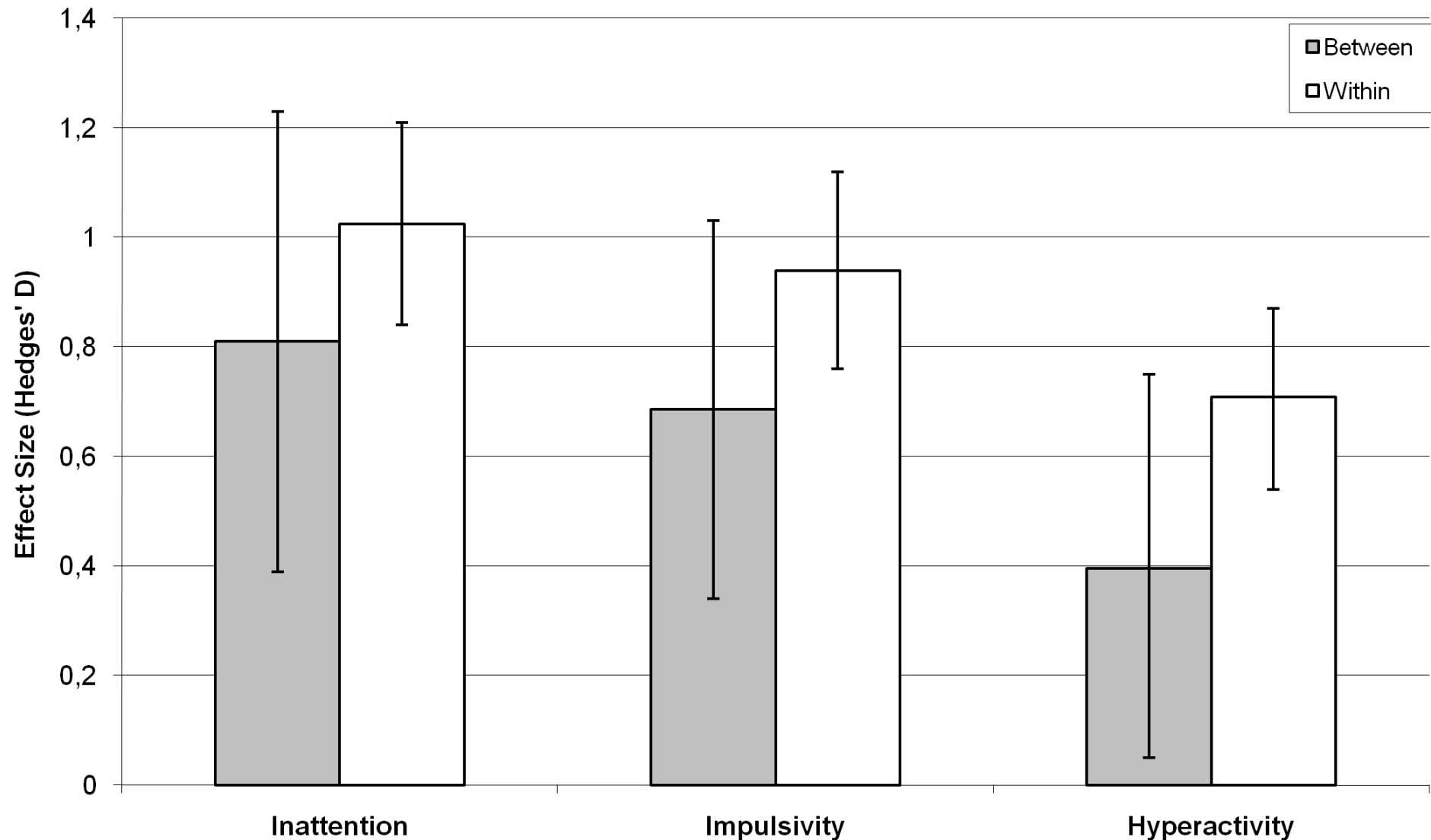
Green lines:
NF vs.
Stimulant
medication
group



Effect sizes
of within
subject
studies with
95% CI



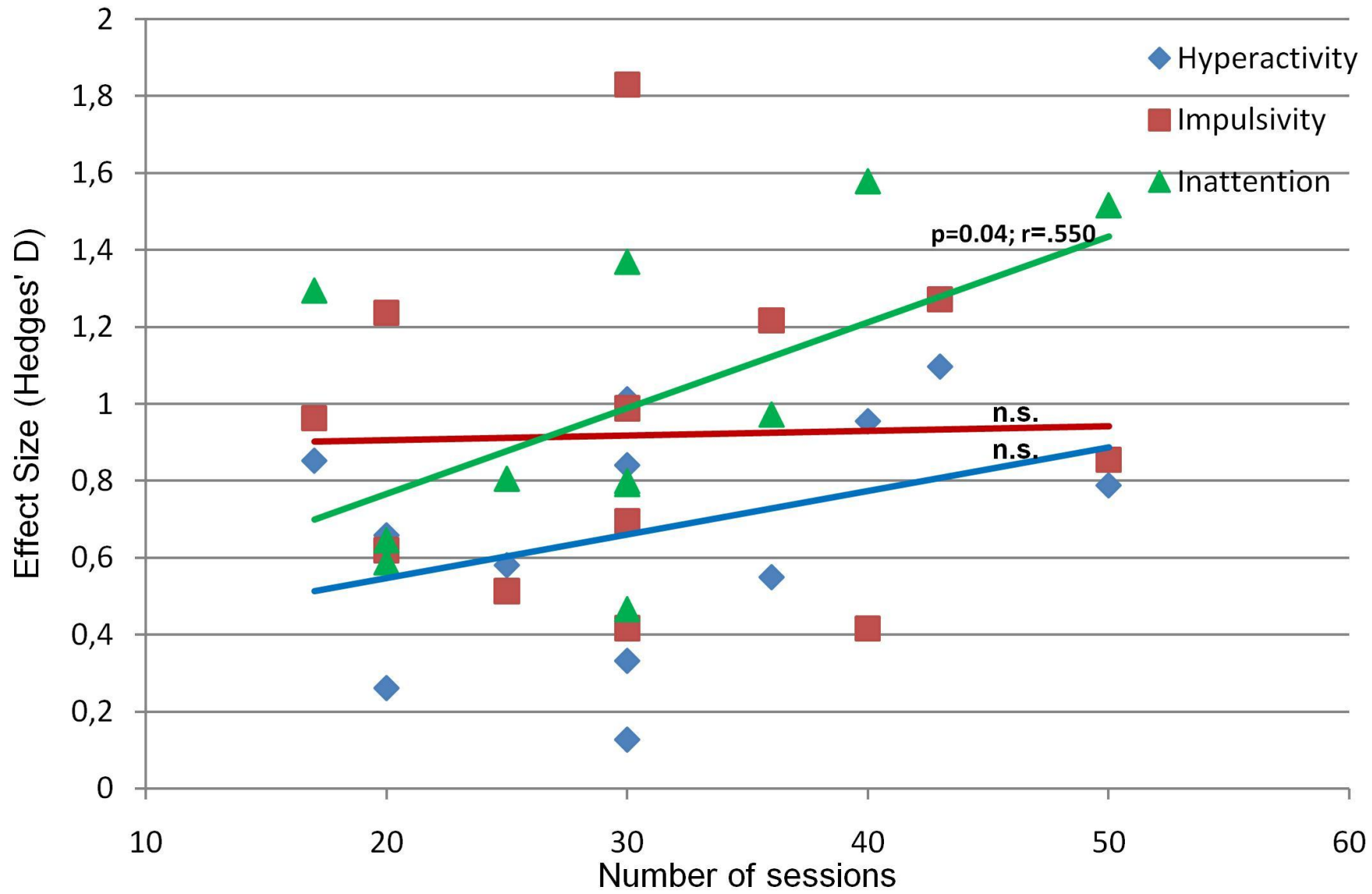
Grand mean effect sizes for between and within subject studies with 95% confidence intervals



Post-hoc analysis

- NO difference in ES for different Neurofeedback protocols (SCP; SMR/Theta and Beta/Theta!)
 - Significant difference between randomized and non-randomized studies for Hyperactivity only
 - No relation with year of publication
 - Significant correlation between # sessions and Inattention; not for Impulsivity and Hyperactivity
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The effect of number of sessions



Placebo Controlled studies: UNPUBLISHED

- Fine, Goldman & Sandford (1994): Captain log control group.
 - Orlandi & Greco (2005; Smart Brain Technologies): J&J sponsored study; 47% drop-out in Placebo group: ES Connors=0.90; ES CGI:=1,62.
 - Picard, Achim, Moreau (2006): Neurofeedback > Placebo and Waiting list group
 - DeBeus (2006): Play Station Neurofeedback > Placebo.
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- WHY NOT PUBLISHED???

Criticisms (1)

- Randomization
 - Small sample-sizes
 - Adequate control groups
 - Journal of publication
 - Pre- and post QEEG differences
 - Long term effects
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Criticisms (2)

- **Long term effects:**
- Heinrich et al. 3 months follow-up for the SCP group
 - All measures improving further (Heinrich, personal communication: Unpublished results).
- Strehl et al. 6 months follow-up
 - Scores improved even further as compared to the end of treatment.
 - **A 2-year follow-up** for this study showed that all improvements in behaviour and attention turned out to be stable. Test results for attention and some of the parents' ratings once more improved significantly. In addition, EEG-self regulation skills turned out to be still preserved, indicating that these children were still able to successfully regulate their EEG.
 - Taken together, it can be concluded that the clinical effects of Neurofeedback are stable and might even improve further with time. This, in contrast to stimulant medication.

Conclusion

*“Due to the inclusion of some very recent and sound methodological studies in this meta-analysis many potential confounding factors have been addressed and the clinical effects of Neurofeedback in the treatment of ADHD can be regarded as **clinically meaningful with large effect sizes for Inattention and Impulsivity and a medium ES for Hyperactivity.***

The three randomized controlled trials from Bakshayesh, Gevensleben et al. and Holtmann et al. have shown Neurofeedback to be superior to a (semi-active) control group. The semi-active control group in these studies can be regarded as a credible sham control providing an equal level of cognitive training and client-therapist interaction.

Therefore, in line with the guidelines for rating clinical efficacy, we conclude that Neurofeedback treatment for ADHD can be considered ‘Efficacious and Specific’ (level 5) with a high ES for inattention and impulsivity and a medium ES for hyperactivity.”

However...

- This does NOT imply Neurofeedback is Evidence-Based for everything!!!
 - Neurofeedback clinicians take your responsibility...
 - Practice and communicate Evidence-Based!
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- Thanks for your attention!

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