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A Meta-Analysis of the Distinct Effects of Neurofeedback (Particularly TBR) on Inattention and Hyperactivity

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ABSTRACT

This meta-analytical study examined the effect of neurofeedback on reducing both the (a) inattentive and (b) hyperactive / impulsive components of children diagnosed with Attention-Deficit / Hyperactivity Disorder (ADHD). The main finding of the meta-analysis was that theta-beta ratio training achieved identical, statistically significant, and practically large effects on both inattention (g = 0.92) and hyperactivity / impulsivity (g = 0.77). An analysis of the literature indicates that the effectiveness of theta-beta ratio-based neurofeedback appears to derive from a general, top-down effect applicable in the frontal regions of the brain, particularly areas and structures related to information processing. One recommendation emerging from the meta-analysis is for neurofeedback practitioners and researchers to better document details related to site placement and bandwidths in order to identify better protocols based on theta-beta ratios. In addition, the importance of alpha generation was highlighted as a means of going beyond static theta-beta ratios in both the diagnosis of ADHD and the measurement of neurofeedback protocol success over time.

Keywords

Neurofeedback, ADHD, Biofeedback, Inattention.

Introduction

The worldwide prevalence of Attention-Deficit / Hyperactivity Disorder (ADHD) has been estimated [1] at 5.29%. According to the Centers for Disease Control and Prevention [2], slightly more than one out of ten American children have ADHD—with the prevalence being 14.6% among boys and 6.9% among girls. Given the intrinsic attentional demands of the information age [3], ameliorating ADHD is a public health priority, especially with respect to children [4]. ADHD reduction is likely to result in widespread social benefits, not only benefits to ADHD sufferers themselves. For example, Robb et al. [5] noted that the surplus annual cost of an ADHD-diagnosed student in American schools is $5,007. In another study [6], adults with ADHD were found to account for over €20,000 in annual surplus cost burden—representing the costs of greater criminality, greater use of state services, and reduced contribution to taxes—to Denmark. Clearly, individuals and societies have a great deal to gain from reducing the prevalence and intensity of ADHD.

The potential of neurofeedback (NF) to reduce ADHD symptoms, particularly among children, is well documented in studies, including several of the studies that served as a basis for the statistical meta-analyses presented below. However, there are two ongoing questions requiring further empirical attention: (1) Is NF more effective for the inattention (IA) vs. hyperactivity / impulsivity (HI) domains of ADHD, as distinctly recognized by the American Psychiatric Association [7]? (2) Does the selection of a specific NF protocol—encompassing variables such as sites and frequencies—determine whether NF has more of an effect on IA or HI?

ADHD has been described [8] as general hypofunction and structural inefficiency in the frontal regions of the brain. In diagnostic clustering, as well as in neuroimaging, low attentional control resulting from frontal region deficits [9] is generally responsible for both IA and HI. Neuroimaging offers one approach

to explore the potential overlap between IA and HI. If similarly situated hypoactivity or structural deficits are observed in the brains of IA- and HI-dominant forms of ADHD, it can be hypothesized that IA and HI are highly correlated manifestations of the same underlying kinds of neural deficits. In the absence of a single neural marker [10] for ADHD, approaches such as neuroimaging and biostatistics are reliant on complex information—such as under-activation in more than one frontal region or the expression of a cluster of genes—in order to draw inferences about the nature of ADHD. NF also provides a lens through which to understand the interrelationship of the two main components of ADHD.

Analyzing the relationship between (a) the treatment of NF and (b) the outcomes of IA and HI is useful for two reasons. First, such an analysis triangulates existing findings from domains such as neuroimaging and biostatistics. If, for instance, NF has a similar effect on IA and HI, one potential explanation of this similarity is that NF addresses higher-level frontal function in a manner that trickles down to the specific manifestations of IA and HI. Second, such an analysis is useful for NF practitioners themselves. Analysis can reveal whether NF applied to a single location (for example, Cz or Fz) on the skull affects both IA and HI in a similar manner, offering support for a simple protocol for ADHD symptom remediation. On the other hand, analysis can also reveal whether NF's impact on IA and HI might be due to differing placements and protocols, in which case NF practitioners could become better informed about which protocols are more relevant to IA and which protocols might be better suited for HI.

Conclusions that can be reached on the basis of meta-analysis are necessarily limited by weaknesses in study design. Therefore, for example, the absence of studies that control for placebo-expectancy effects in NF for ADHD means that it remains unclear whether effects attributed to NF can more properly be attributed to the placebo effect. The existing studies have several other weaknesses—for instance, in the design or even presence of control conditions—that limit the force of conclusions that can be drawn from meta-analysis.

Methods

The statistical meta-analysis has been presented before the systematic review in line with the mixed-methods approach of sequential explanation, in which qualitative evidence is provided in order to explain previously presented quantitative findings [11]. Individual meta-analyses were conducted to address the following four research questions that motivated the study:

- What is the 95% confidence interval (*CI*) for the Hedges' *g* pooled effect size of NF as a predictor of IA symptom improvement?
- What is the 95% *CI* for the Hedges' *g* pooled effect size of NF as a predictor of HI symptom improvement?
- Is there a statistically significant difference between (a) NF as a predictor of IA symptom improvement and (b) NF as a predictor of HI symptom improvement?
- How do differences in NF protocols account or fail to account for the meta-analytical findings related to 1-3?

Hedges' *g* was chosen as the measure of effect size because of its correction of Cohen's *d*'s small-study bias [12], and a random-effects model was chosen for its superiority [13] when dealing with relatively larger numbers of included studies. As Guolo and Varin noted, fixed-attempts meta-analytical models are often applied when analyzing the results of less than 10 studies. This threshold was exceeded in the sample size (*k*) of studies assembled for research questions 1, 2, and 3. In addition, because of variability between the studies themselves (in geographical, temporal, and NF protocol terms), a random effects model appeared to be justified.

Finally, the *Q* statistic for both IA and HI studies was statistically significant. Borenstein, Hedges, Higgins, & Rothstein [14] stated that a significant *Q* statistic indicated the existence of sufficient heterogeneity (subsequently quantifiable by I^2 and T^2) in effect size to justify a random-effects model. For included HI studies, $Q = 151.49$, $p < .0001$. For included IA studies, $Q = 158.74$, $p < .0001$.

Borenstein et al. [14] provided an extensive discussion of meta-analytical heterogeneity that guided the discussion of IA and HI meta-analytical results. Borenstein et al. described the *Q* statistic and its accompanying *p*-value as relevant solely to "the viability of the null hypothesis (*Is the true dispersion exactly zero*) and not the amount of excess dispersion" [14]. Borenstein et al. defined T as "the [estimated] standard deviation of the true effects" [14], with τ indicating "the actual standard deviation" [14]. Next, Borenstein et al. defined I^2 as "s measure of *inconsistency* across the findings of the studies, and not as a measure of the real variation across the underlying true effects" [14]. In summary, "The statistics *T2* (and *T*) reflect the *amount* of true heterogeneity (the variance or the standard deviation) while I^2 reflects the proportion of observed dispersion that is due to this heterogeneity" [14]. For the meta-analyses of both IA and HI, *Q* statistics (and their accompanying *p*-values), T^2, and I^2 were all calculated and interpreted in alignment with Borenstein et al.'s guidance in *Introduction to Meta-Analysis*.

All statistical analysis was carried out in the R open-source statistical language, with RStudio as the integrated development environment and the Meta library within R serving as the meta-analytical package. The statistical code is available on request.

An important resource in calculating weights for the studies was the DerSimonian and Laird [15] method, which can be applied from within R's Meta library. In this method, the weight for a study, *i*, is a function of variance, as follows:

$$W_i^* = \frac{1}{V_{Yi}^*} = \frac{1}{V_{Yi} + T^2}$$

Total study variance, or V_{Yi}, is thus the sum of T^2 (between-study variance) and within-study variance, or V_Y. The inverse of total study variance is the weight. This method remains a popular means of weighting studies included in a random-effects meta-analysis [14]. In the context of the meta-analyses of the effect of NF on IA

and HI, the use of the DerSimonian and Laird approach meant that larger-sample studies were not necessarily weighted more highly.

Specifically, the Kaiser and Othmer [16] study, by virtue of a sample size (n = 1,089) substantially larger than the sample sizes of the other studies, would have exercised higher leverage on the findings in a fixed rather than random-effects model. In addition to the theoretical [13] advantages of a random effects model when dealing with a higher k, it should be noted that such a model also corrects, in this instance, for the influence of Kaiser and Othmer's study, which, despite its large size, was still geographically limited and is also dated in comparison to the other studies in the meta-analysis.

In the forest plots generated for the meta-analysis, standardized mean difference, or SMD, indicates Hedges' g. This use of *SMD* as a synonym for *Hedges'* g is endorsed in the *Cochrane Handbook for Systematic Reviews of Interventions*:
"Effect sizes typically, though not always, refer to versions of the standardized mean difference [SMD]. It is recommended that the term 'standardized mean difference' be used in Cochrane reviews in preference to 'effect size' to avoid confusion with the more general plain language use of the latter term as a synonym for 'intervention effect' or 'effect estimate'" [17]. The particular definition of standardized mean difference used in Cochrane reviews is the effect size known in social science as Hedges' (adjusted) g., (Choosing effect measures and computing estimates of effect).

The goal of the meta-analyses was to compare the 95% *CI*s for the effect—that is, the SMD / Hedges g—of NF on both IA and HI. Reverse coding was utilized in order to represent positive g values as an improvement in attention; conceptually, such an outcome is the same as a decrease in inattention, but the positive g values simplify interpretability.

PUBMED was the database searched for studies to include in both the IA and HI meta-analyses. The PUBMED searches were augmented with studies known to the authors but not archived in PUBMED. Figures 1 and 2 are the PRISMA flow diagrams related to study identification and inclusion.

Many studies were eliminated from consideration because they did not contain before-and-after measures of either IA or HI in relation to NF. Other studies were eliminated because they did not have ADHD-diagnosed children as their subjects. The studies possessed various limitations, some of which have been noted explicitly in the discussion following the presentation of results.

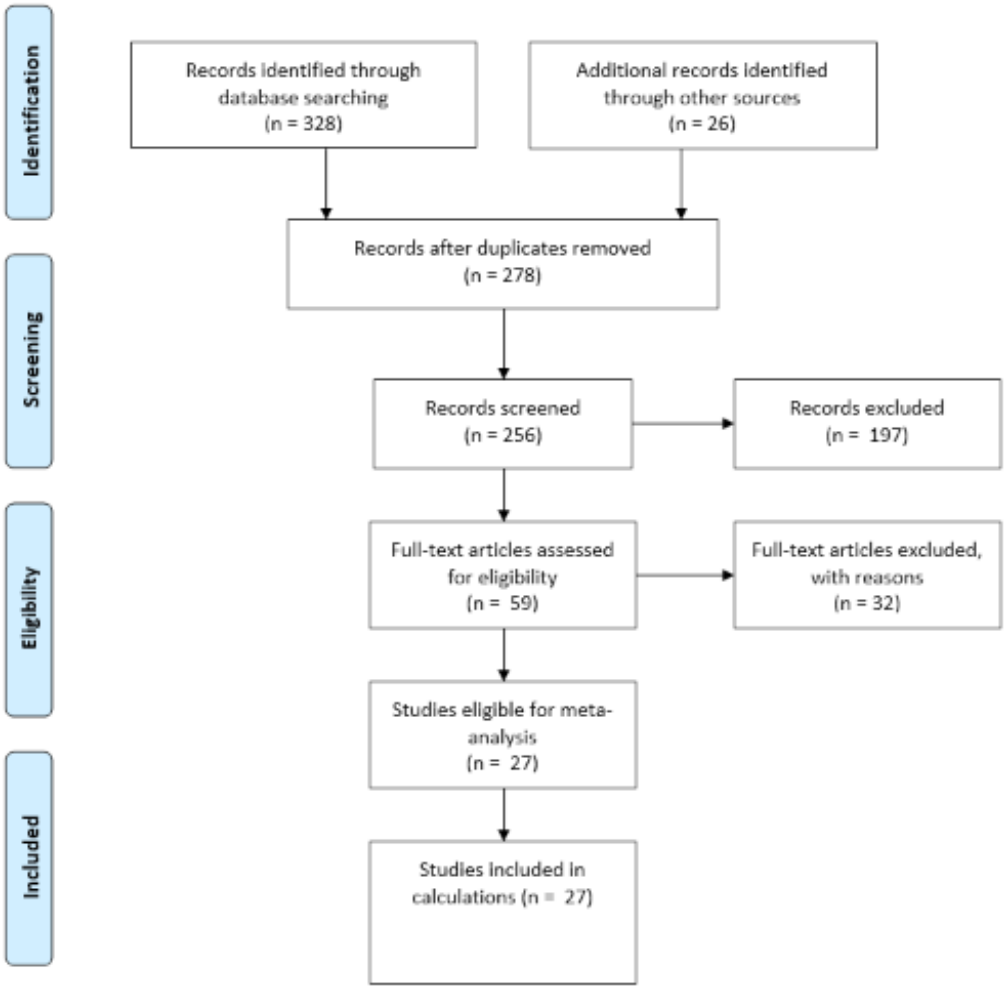

Figure 1: PRISMA flow diagram, IA studies.

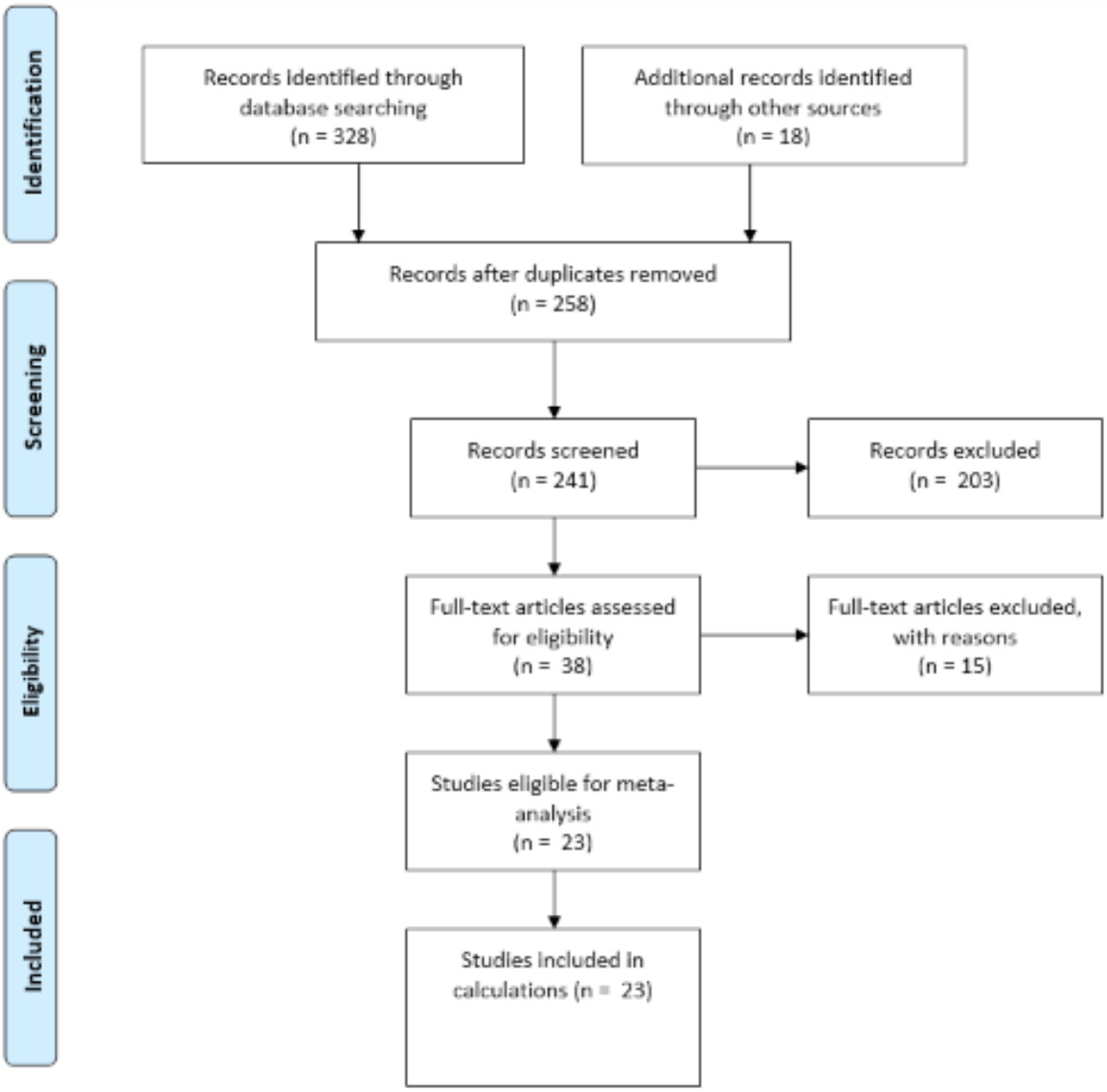

Figure 2: PRISMA flow diagram, HI studies.

Results

The results of the meta-analysis are presented in order of the research questions. Each research question is accompanied by relevant meta-analytical statistics and visualizations. A separate discussion section, following the results, reflects on the findings from research questions 1 through 4 in terms of existing research.

RQ1 Results

The first research question of the study was as follows: What is the 95% *CI* for the Hedges' *g* pooled effect size of NF as a predictor of IA symptom improvement?. The calculated Hedges *g* for the sample of included studies (k = 27) was 0.92 (0.71, 1.14), that is, close to a standard deviation and thus achieving what Cohen (2013) described as a large effect size.

If I^2 can be considered as "a kind of signal-to-noise ratio" [14], then a high I^2 means, "Most of the observed variance is real" [14]. In both RQ1 and RQ2, high I^2s were obtained, suggesting that variations in protocol, NF therapist skill, client characteristics, and other factors might be responsible for variance. In addition, as Borenstein et al. [14] indicated, the square root of T^2 can be treated as a means of estimating true effects around an effect size or SMD, by passing the ordinary method of deriving a pooled effect size from the weighted effect sizes of individual studies (the default method by which pooled effect sizes were generated for meta-analyses of IA and HI). For RQ1, $T \approx 0.49$, meaning that 95% of the effects of NF on IA might fall in the range of 0.43 to 1.41.

RQ2 Results

The second research question of the study was as follows: What is the 95% *CI* for the Hedges' *g* pooled effect size of NF as a predictor of HI symptom improvement?. The calculated Hedges *g* for the sample of included studies (k = 23) was 0.77 (0.63, 1.00), that is, slightly over three-quarters of one standard deviation and thus achieving what Cohen [18] described as a medium effect size—just missing the cutoff of 0.80 required for a large effect.

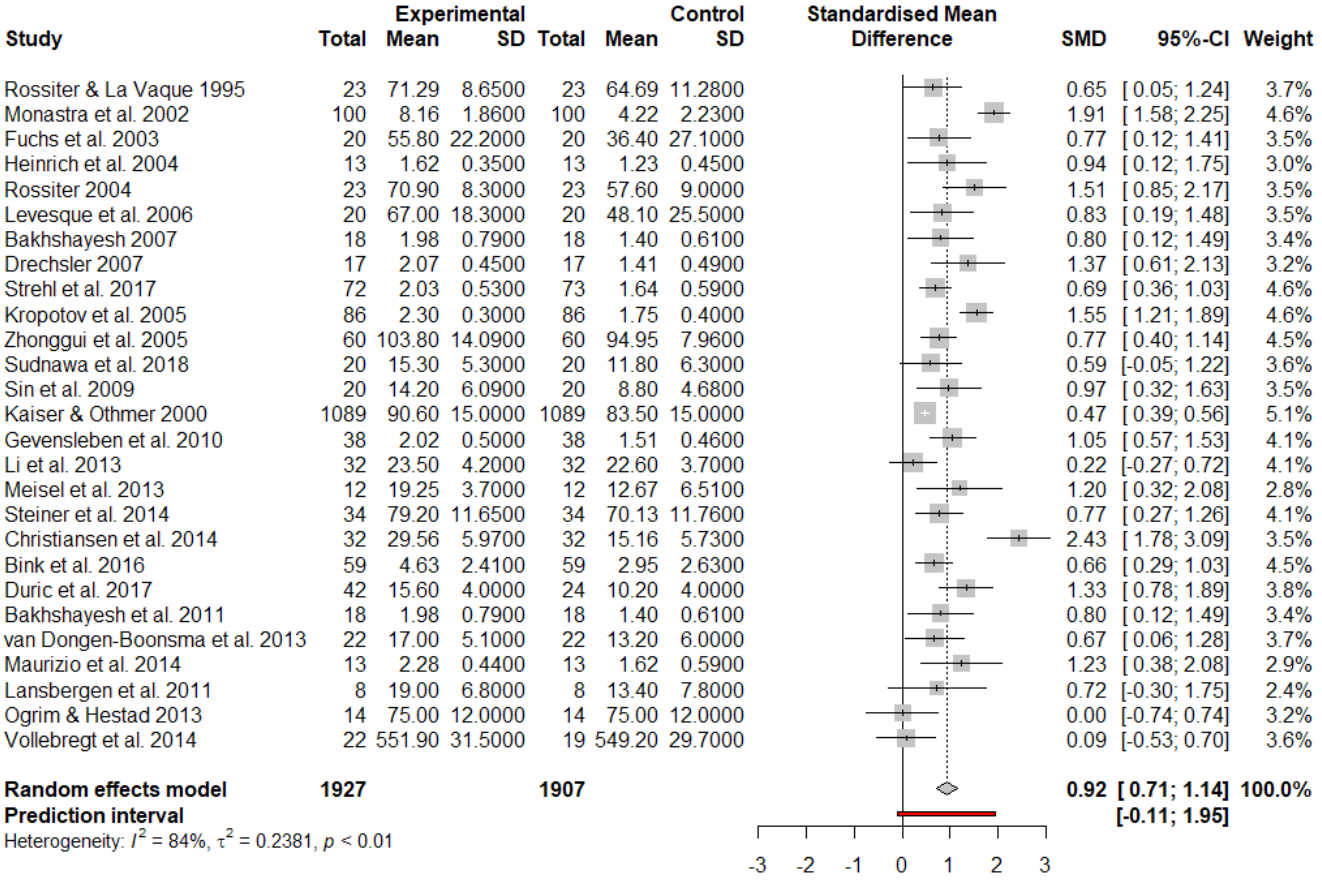

Figure 3: Forest plot, random effects model, NF's impact on IA. 95% *CI* of I^2: [77.2%, 88.2%].

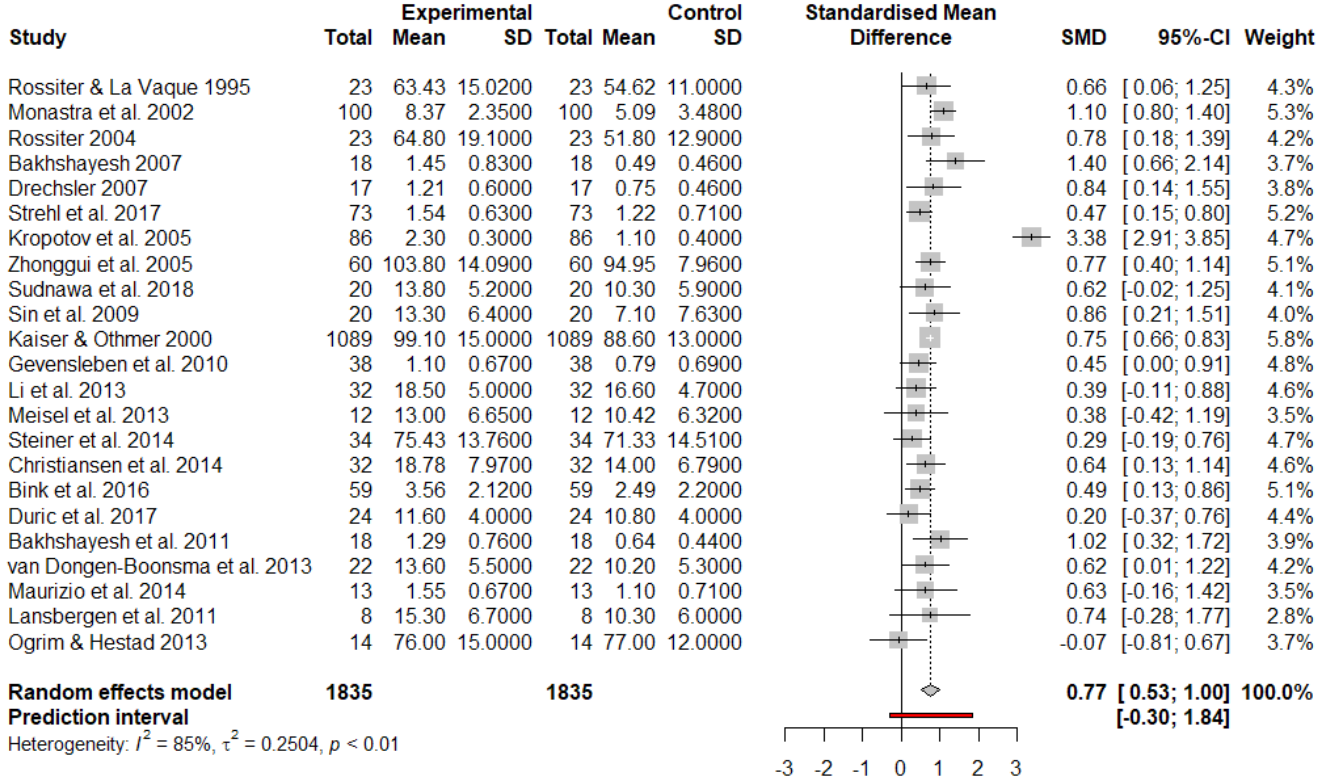

Figure 4: Forest plot, random effects model, NF's impact on HI.

In the sample of studies for the second research question, studies that did provide a distinct assessment for HA were excluded; otherwise, there is substantial overlap in the sample of studies for the first research question and the sample of studies for the second research question.

For RQ2, $T \approx 0.50$, meaning that 95% of the effects of NF on IA might fall in the range of 0.27 to 1.27.

RQ3 Results

The third research question of the study was as follows: Is there a statistically significant difference between (a) NF as a predictor of IA symptom improvement and (b) NF as a predictor of HI symptom improvement? It is clear from the previous sets of results that the 95% *CI* of *g* for NF's effect on IA (0.71, 1.14) substantially overlaps with the 95% *CI* of *g* for NF's effect on HI (0.53, 1.00). The overlap exists regardless of how the 95% *CI* is calculated. For instance, using the *T* method of estimating a 95% *CI* [14], the range of NF's effects on IA [0.43, 1.41] is comparable to the range of NF's effects on HI [0.27, 1.27].

RQ4 Results

The fourth research question of the study was as follows: How do differences in NF protocols account or fail to account for the meta-analytical findings related to research questions 1-3? The first step in answering NF was to tabulate the studies utilized in the meta-analyses for research questions 1 and 2 in a manner that captured NF protocols. When studies included shifting protocols or did not otherwise disclose discrete protocols, they were marked as such.

The majority of studies included in both the IA and A meta-analyses applied the theta / beta ratio (TBR) protocol; there were also some studies that applied slow cortical potentials (SCPs) and some studies in which different, unspecified protocol types were applied to different participants. Given the predominance of TBR protocols, new meta-analyses were conducted solely on studies that applied this protocol to ADHD-diagnosed children.

Table 1: Assessment of Studies for NF Protocol.

IA Study	Included in HA?	NF Protocol
Rossiter & La Vaque (1995)	Yes	Shifting
Monastra et al. (2002)	Yes	TBR
Fuchs et al. (2003)	No	TBR
Heinrich et al. (2004)	No	TBR
Rossiter (2004)	Yes	Shifting
Levesque et al. (2006)	No	TBR
Bakhshayesh (2007)	Yes	TBR
Drechsler (2007)	Yes	SCP
Strehl et al. (2017)	Yes	SCP
Kropotov et al. (2005)	Yes	TBR
Zhonggui et al. (2005)	Yes	TBR
Sudnawa et al. (2018)	Yes	TBR
Sin et al. (2009)	Yes	TBR
Kaiser & Othmer (2000)	Yes	SCP
Gevensleben et al. (2010)	Yes	Shifting
Li et al. (2013)	Yes	TBR
Meisel et al. (2013)	Yes	TBR
Steiner et al. (2014)	Yes	TBR
Christiansen et al. (2014)	Yes	SCP
Bink et al. (2016)	Yes	TBR
Duric et al. (2017)	Yes	TBR
Bakhshayesh et al. (2011)	Yes	TBR
Van Dongen-Boonsma et al. (2013)	Yes	TBR
Maurizio et al. (2014)	Yes	TBR
Lansbergen et al. (2011)	Yes	Shifting
Ogrim & Hestad (2013)	Yes	TBR
Vollebregt et al. (2014)	No	Shifting

Delimiting the studies to TBR NF's effects on inattention (k = 17), Hedges' g was found to be 0.91 [0.65, 1.16], which was very similar to the point estimate (g = 0.92) and 95% *CI* [0.71, 1.14] when all the relevant studies (k= 27) were included in the meta-analysis. Similarly, delimiting the studies to TBR NF's effects on HI (k = 15), Hedges' g was found to be 0.91 [0.62, 1.21], which was close to the point estimate (g = 0.77) and 95% *CI* [0.53, 1.00] when all the relevant studies (k= 23) were included in the Meta analysis.

The fourth research question was only partially answered, because the number of included SCP studies was too low to support either a distinct meta-analysis or the inclusion of protocol type (TBR vs. SCP) as a covariate in the meta-analysis. However, given the large number of TBR studies, it was appropriate to conduct new meta-analyses for TBR alone and identify any resulting dissimilarities from the main meta-analyses. In this respect, the primary finding was that the effect, g, of TBR-based NF on both IA and HI were not significantly different from the overall effect of NF, regardless of whether the underlying modality was TBR, SCP, or shifting (that is, with different protocols applied to different children based on clinical customization). Therefore, some explanation should be provided as to why TBR in particular was associated with essentially identical effects on IA and HI.

Publication Bias

There is evidence of publication bias in the IA studies. Egger, Smith, Schneider, and Minder's (1997) linear regression test of funnel plot asymmetry, applied to the IA studies, indicated a rejection (t = 2.68, p = .013) of the null hypothesis of a 0 intercept, indicating the possibility of publication bias. However, the null could not be rejected in the case of HI studies, t = 0.06, p = 0.956, indicating that the HI studies are less likely to have been subject to publication bias. Funnel plots for both the IA and HI studies appear below.

Discussion

The underlying theoretical basis for TBR is that, in terms of brainwaves, higher theta is associated with an unfocused, unaroused, slow-tempo state, whereas higher beta is associated with higher arousal [19]. Therefore, a relative increase in the portion of beta to theta should result in improved attentional resources, as Lubar and Lubar [20] were probably the first to claim in the context of NF practice specifically.

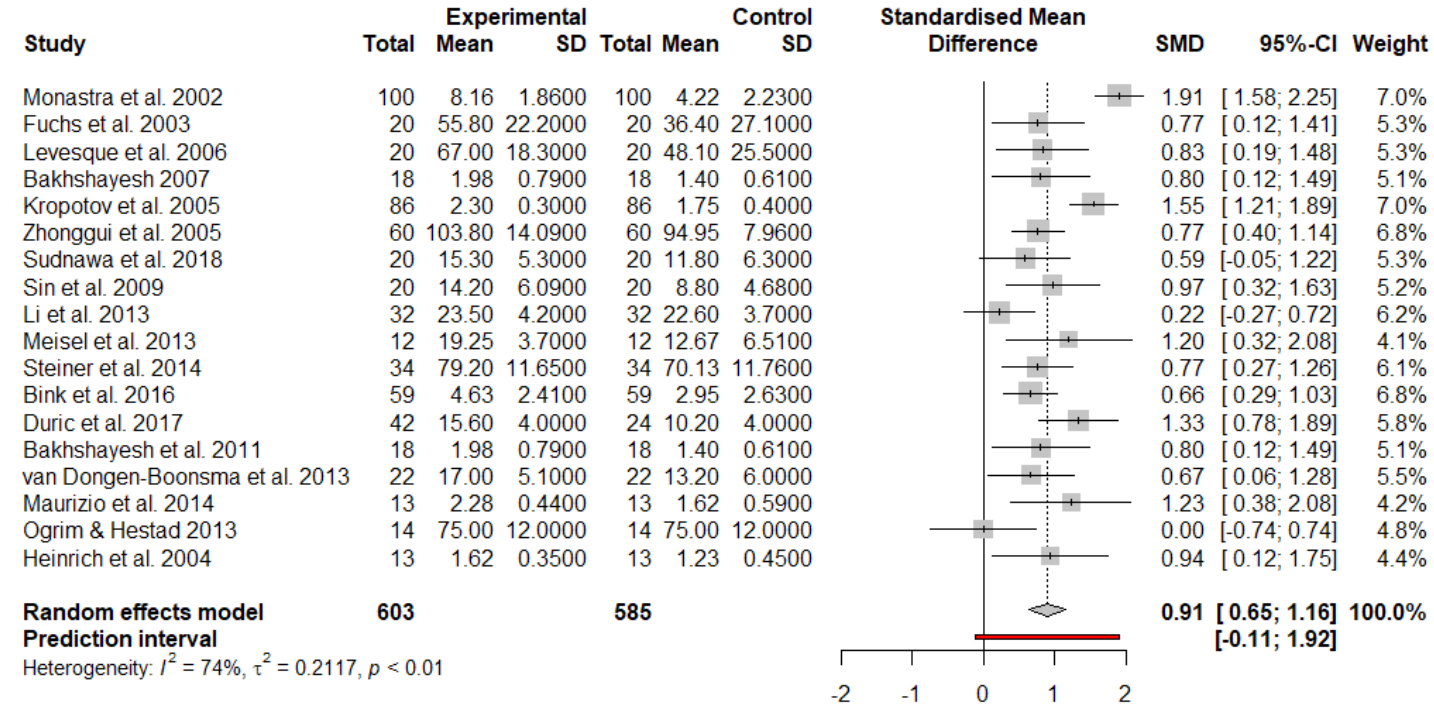

Figure 5: Forest plot, random effects model, NF's impact on IA, TBR only.

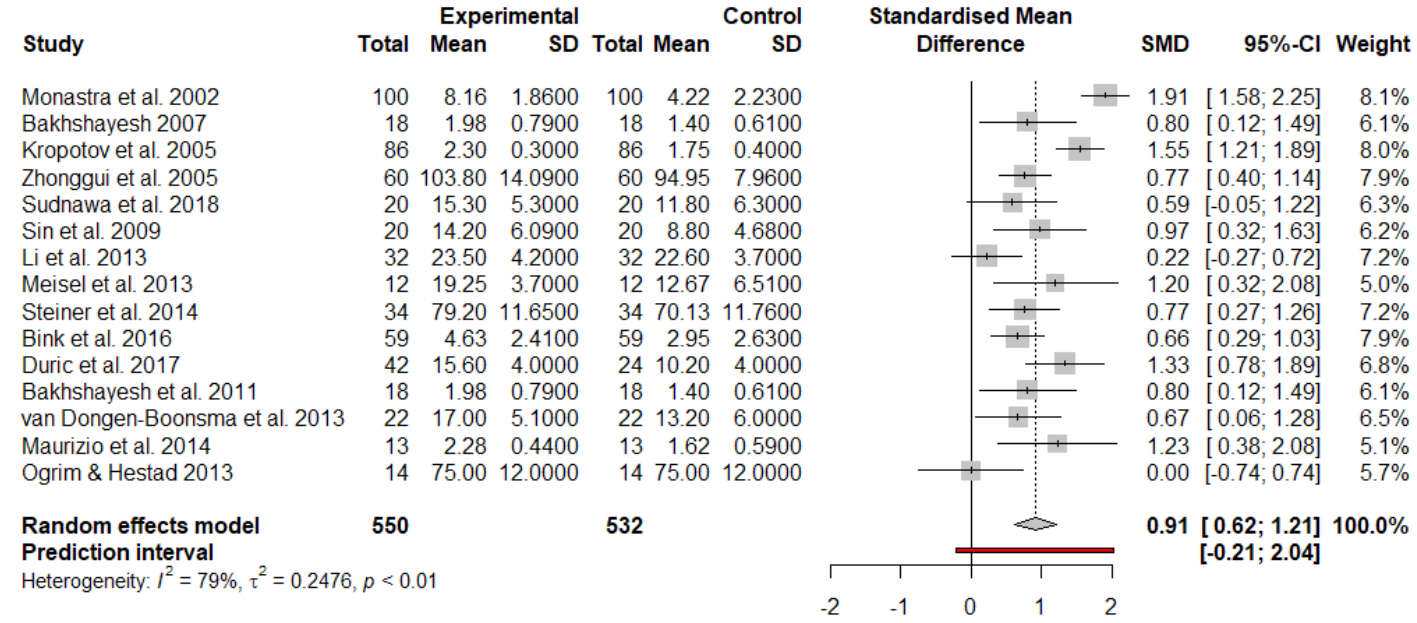

Figure 6: Forest plot, random effects model, NF's impact on HI, TBR only.

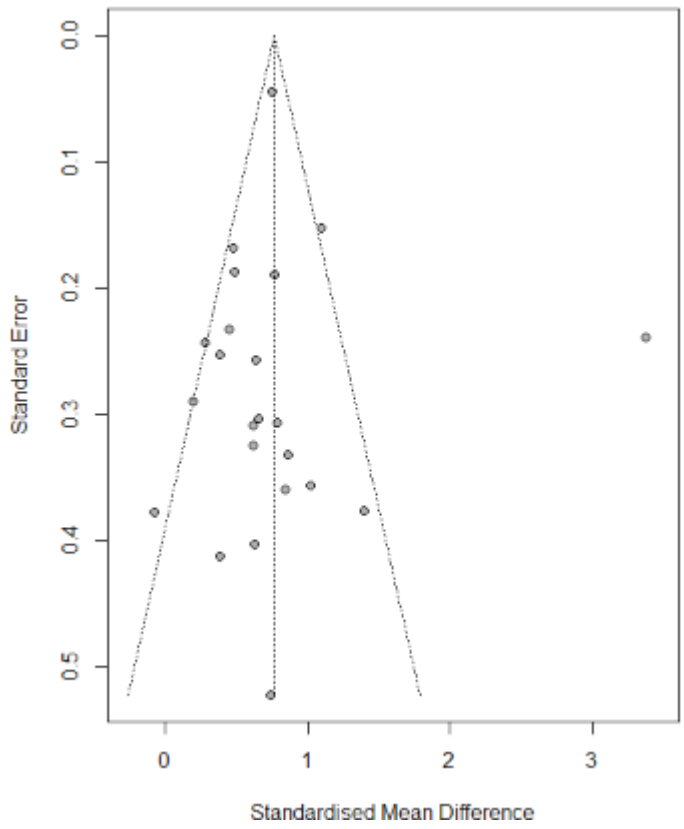

Figure 7: Funnel plot, HI studies.

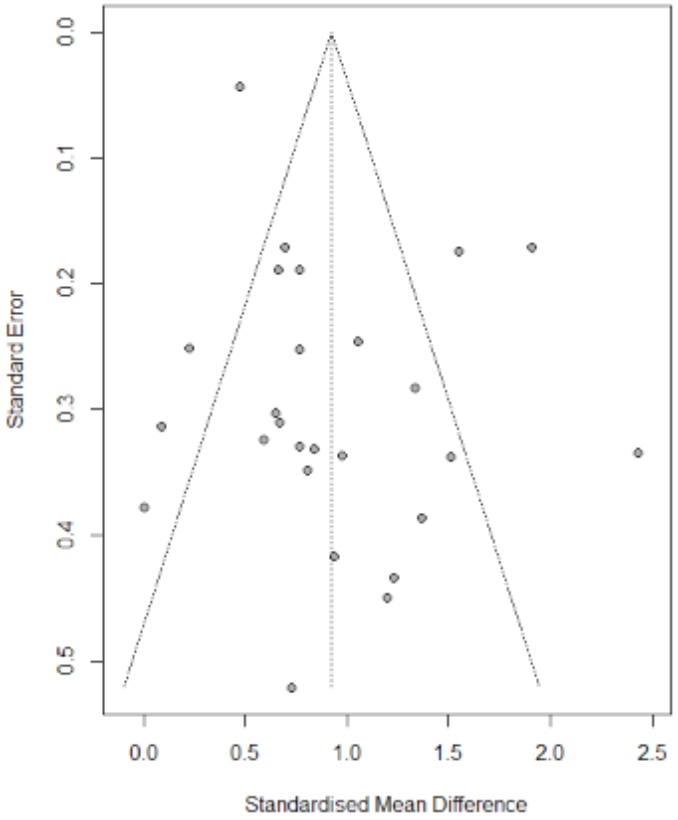

Figure 8: Funnel plot, IA studies.

Given the interconnectedness of attention, hyperactivity, and impulsivity [9], it is possible that the attention-augmenting effect of TBR protocols carries over to HI, resulting in a single-protocol approach to ADHD—such as the TBR training espoused by Lubar et al. [19]. Insofar as TBR could be a marker of general cognitive processing ability [21], and insofar as ADHD is itself a result of deficits in cognitive processing ability [22], the effectiveness of NF interventions for ADHD-diagnosed children appears to be somehow top-down in nature.

Heinrich et al. [23] disclosed that, although TBR is more strongly apparent in the frontal regions (F3, Fz), TBR can also be reliably measured and trained at the top of the head (Cz), which Lubar [24] also recommended. Given that ADHD can be characterized as a frontal deficit [10], it might be conceptually plausible that frontal training is superior to Cz training, especially given the effects measured by Heinrich et al. One point of interest in this context is Steinberg et al.'s [25] finding that NF's effects on TBR were roughly the same at Fz and Cz (although, because this finding was from one adult, it might not apply to the NF training of ADHD-diagnosed children).

Ultimately, the question of why TBR NF works in reducing ADHD symptomatology cannot be answered definitively on the basis of either available data or a compelling and comprehensive account of ADHD itself. As Saad et al. (2018) noted, the Food and Drug Administration (FDA) of the United States has approved TBRs as a basis for ADHD diagnosis, and the more pressing question has become how to further refine diagnostic criteria, as well as NF practice, under the TBR heading. Saad et al.'s contribution to the contemporary diagnostic utilization of TBRs was to suggest the concept of personalized diagnosis based not on a resting TBR but on the ability of individuals to generate alpha waves when presented with attentional tasks. This recommendation is conceptually sound in that a child with a high TBR who is able to generate relatively more alpha when presented with an attentional task might, in essence, be given to daydreams or similar states that can easily be replaced by appropriate attention. On the other hand, a child with the same TBR, but one who is unable to generate more alpha when needed, would appear to better fit the diagnostic criteria of ADHD. The point to which Saad et al. aptly called attention is that TBR should not be utilized as a static criterion; it should inform a more dynamic approach to diagnosis in which the generation of alpha subsequent to attentional demands should also be taken into consideration.

One possible suggestion for future research is for NF scholars to present more detailed data in a manner that allows the analysis of NF outcomes with reference to distinct NF placements, if not necessarily protocols. If the meta-analyses of the effects of TBR NF on IA and HI presented above are accurate, then it can be plausibly argued that altering the TBR ratio is NF's main contribution to the remediation of ADHD symptoms. However, there remains the question of whether TBR NF is more effective in the frontal regions (F3, Fz) in comparison to the top of the head (Cz). There are also numerous variations in specific TBR NF protocols whose

effectiveness vis-à-vis specific ADHD outcomes (such as IA and HI symptom reduction) needs to be measured. Not all NF researchers are punctilious about documenting their exact placements, training bands, and other protocol variables in a manner that can allow meta-analysts to measure outcomes in a more precise manner. Despite the rapid uptake of NF in the therapeutic community, the mainstreaming of NF would appear to require greater precision in both the reporting and the meta-analysis of symptom reduction data keyed to precisely described NF protocols.

The point raised by Saad et al. [26] with respect to the importance of alpha generation also raises methodological questions that should capture the interest of future researchers. If, for instance, the NF basis of ADHD is described not as a generic, static cutoff for TBR based on analysis of a large sample but as the inability to transition from higher TBRs to higher relative alpha production, then more complex forms of statistical analysis are necessary to diagnose ADHD among children. One possible approach future researchers could take is to consider a different ratio, one that takes both TBR and the theta-alpha ratio (TAR) into account. For instance,

$$\frac{\Delta TAR}{\frac{1}{\Delta TBR}}$$

Is a ratio that will increase more rapidly in magnitude in the presence of both (a) a relative decrease (vis-à-vis beta) in the production of theta; and (b) a relative increase (vis-à-vis beta) of alpha. This ratio is a simple means of going past TBR cutoff as a diagnostic criterion. For change in alpha to be validly measurable, children have to be presented with a universal attention task (such as the Stroop task), many of which already exist and are widely utilized by psychologists and researchers in related fields. NF and the administration of attentional tasks would therefore have to overlap in the task of diagnosis, with NF practitioners themselves becoming adept in giving such tasks to experimental subjects or working more closely with professionals who already possess the requisite expertise.

In such an approach, the assumption is that of a comparison between rest and some form of activity. Researchers [27-29] have already underlined the importance of measuring differences in brainwaves—and brainwave ratios—in this manner, offering NF practitioners an alternative to static, at-rest TBR measurements as diagnostic criteria. However, regardless of whether the primary concern is diagnostic or an attempt to understand how well an NF has worked over time, NF practitioners and researchers should strongly consider the use of cross-sectional approaches designed to measure different states, whether (a) the at-rest and task-engaged TBR of a subject or (b) at-rest TBR at measured at the onset of NF and at-rest TBR after some number of sessions.

In working with an individual client, NF practitioners applying TBR for ADHD symptom reduction should understand how to apply basic statistical principles to calculate whether there has been a significant change in TBR. As there is substantial evidence—as in the meta-analyses presented above—for TBR-targeting NF as a means of reducing ADHD symptoms, NF practitioners should in fact be able to determine whether their training has achieved the desired effect of reducing TBR over time.

$$TBR_{mean} \pm 1.96\left(\frac{TBR_{SD}}{1000}\right)$$

The formula above provides a 95% *CI* for TBR based on the mean and standard reported by NF software (such as EEGer), with *n* arbitrarily set to 1,000 (indicating a high sampling rate that can be an analogue for *n*). NF practitioners could consider calculating the 95% *CI* for TBR at the first NF session—for example, as the result of a so-called mini map or a more formal quantitative EEG (qEEG) readout—and calculating it again after a certain number of sessions in order to determine whether there has been a significant decline in TBR over some treatment interval.

In general, NF researchers should be proactive in controlling for the placebo effect and adding treatment groups. One of the main criticisms currently leveled against NF is that purported NF treatment effects are actually placebo effects [30]. This criticism can be addressed by incorporating sham NF in future studies of the effect of NF on IA, HI, and related problems. In addition, sham NF can be complemented with concurrent therapies, such as pharmaceutical therapies (themselves accompanied by placebo controls), in order to facilitate comparisons of the relative effectiveness of NF.

Conclusion

The meta-analyses presented above indicate not only that NF is effective in treating ADHD but also, and more specifically, that (a) NF has an identical effect on IA and HI and (b) TBR is the particular NF approach with the best attention in terms of ADHD symptom reduction. While there have been previous meta-analyses involving NF, TBR, and ADHD, there does not appear to have been any attempt to distinguish between the effects of either NF in general or TBR NF in particular on IA and HI. Using the measure of Hedges' *g*, TBR achieved an effect fairly close to 1 standard deviation on both IA ($g = 0.91$) and HI ($g = 0.77$). Therefore, TBR's effect on IA and HI symptom reduction is not only statistically significant; it is, in Cohen's (2013) interpretative scheme, a large effect. The effectiveness of TBR NF appears to be related to a generalized, top-down effect exercised on the frontal regions of the brain, including areas and structures related to information processing.

Because of the variability in TBR NF protocols, practitioners and researchers should consider collecting or providing more precise details related to TBR sites and bandwidth training. Such data are necessary to isolate better TBR protocols—if, indeed, some site placements and bandwidths are better than others in terms of achieving ADHD symptom reduction. Additionally, despite the usefulness of TBR as both a diagnostic tool and a means of measuring the effectiveness of NF over time, practitioners should

give some thought to integrating TAR as well. Integrating TBR with TAR, particularly in the context of before and after NF, can improve on TBR alone as a measure of ADHD intensity in an individual child. Given the immature state of NF research in comparison to other therapeutic and treatment modalities, there is an ongoing need for high-quality data, data analysis, and updated diagnostic and treatment measurement models.

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