

EXECUTIVE FUNCTIONS THROUGH ATTENTION

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Issue Explored

- > In-situ (classroom) implementation of Neurofeedback Training (NT, Figure 1) as a prospective teaching tool for building attention and developing efficacious learning behaviours



Figure 1: Neurofeedback Training set-up. The portable headset sends EEG data via Bluetooth® to the computer, which performs a Fourier transform and provides feedback directly to the student via game play.

Keywords

- > Attention, Biofeedback, Executive Functions, Learning Behaviours, Neurofeedback, NT, Translation

Testable Hypotheses

- > NT efficacious in building sustained attention
- > Association between attention and learning behaviours/executive functions

Methods

- > Pre-experimental design ($O_1 \times O_2$)
- > $O_{1,2}$ – Conners 3, BRIEF (not included), school reporting of learning behaviours (not included), and EEG (not included)
- > X – NT semi-weekly 30-minute training sessions (using MindWave headset) alternating between Focus Pocus and self-selected games from a set pre-purchased from the NeuroSky store
- > Participants in grades 5-8
- > Informed consent & assent prior to enrollment

Observations

- > Results for this research fall into two distinct components; establishing whether NT supports gains in attention (decreases in inattentive behaviours) – corroborating the results achieved in clinical contexts, and identifying whether changes in students' sustained attentional capacity are related to changes in classroom learning behaviours and executive functions. Data from Conners 3 psychometric scales and student report cards will be presented to address these primary concerns.

- > Results support that both teachers and parents observed decreases in the relative occurrence of inattentive behaviours over the time period of participation in NT (refer to Figure 2 for illustration of changes).

Table 2: Summary of results for student's paired t-test for inattentive behaviours

Source of Assessment	Difference	Degrees of Freedom	t_{obs}	t_{crit}	p-value
Teachers*	-3.895	18	-2.194	-1.734	< 0.05
Parents**	-5.286	13	-2.310	-1.771	< 0.05

Background

- > Education is undergoing global reform. Despite a circuitous path, several key features have emerged:
 - Increasingly personalizable learning¹³
 - Expanded accessibility⁹
 - New desired learning outcomes, centred on adaptive competences⁵

Recent developments have largely resulted from sustaining innovations (e.g. increased computer access in the classroom³) and do not address new expected learning outcomes, including higher-order thinking skills, real-life problem solving, and collaboration.⁷ It has been theorized that behavioural (attentional) inhibition is linked to four of these underlying executive functions: working memory, self-regulation, internalizing verbal communication, and behaviour adaptation.^{2,6}

The authors of this presentation hypothesize that building attention – through the implementation of disruptive teaching technologies in the classroom (NT) – will support the development of executive functions and effective classroom learning behaviours.

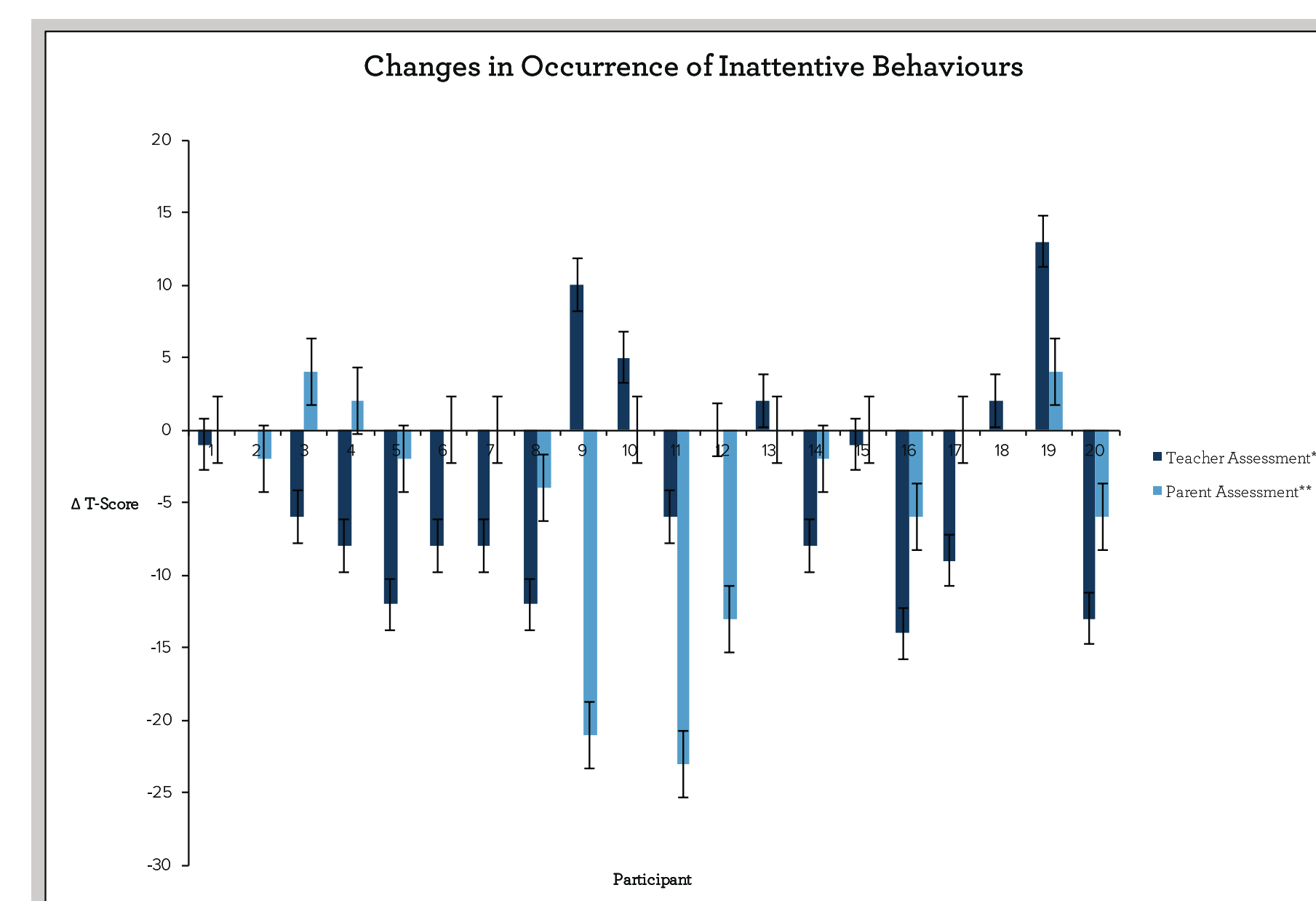


Figure 2: Illustration of changes in inattentive behaviours, calculated as $T\text{-score}_{post} - T\text{-score}_{pre}$ from the Conners 3 psychometric scale. Both teacher and parent assessments are illustrated for all participants. Negative scores indicate decreases in the relative prevalence of inattentive behaviours. Standard error of the mean bars have been included to frame the size of changes.

- > Attention and executive functioning were found to have an association such that gains in attention corresponded with gains in planning, organization, and listening. Refer to tables 3 and 4 for illustration of non-parametric correlation results for parent and teacher assessments, respectively.

Table 3: Summary of non-parametric (Spearman) correlation for pre-test post-test differences between attention and executive functioning for teacher assessments

Source of Assessment	Inattention		Executive Functioning	
	Spearman Correlation	p-value	Spearman Correlation	p-value
Inattention	1	0	0.569	p < 0.05
Executive Functioning	0.569	p < 0.05	1	0

Can Attention be Learned?

- > Although what it means to "pay attention" is common knowledge, few seem able to describe how to attend or know what attention feels like. This inability to delineate such an important autonomous process is central to the challenge of teaching attention and is (at least) partly responsible for attention's extraneous nature to teaching models. Compounding this difficulty, a growing proportion of the population grapples with neurologically-based learning disabilities that involve deficits in attention.⁹ Given the importance of attention in acquiring knowledge and cognitive development, it follows that the treatments and training regimes prescribed for attention would best succeed by directly addressing its neurological basis.

Neurofeedback Training

- > NT teaches individuals to self-regulate by providing direct feedback on temporal and spatial patterns in brain activity. Using EEG measurement, NT rewards individuals for attending effectively, causing them to further attend. This form of learning (operant conditioning) is intrinsic to human growth and development. Repetitive training of particular brain activity patterns remodels the structure of the brain to accommodate the new function. Existing research on attention training has focused on simultaneously maximizing Mu activity and minimizing Theta activity (Table 1).

Table 1: Commonly used brain wave activity patterns for NT

Brain Wave	Frequency Range [Hz]*	Region of Origin	Associated Activity	Used in NT
Delta	0.5-3.0	Anterior (adults), Posterior (children)	Deep sleep	No
Theta	3.5-7.0	Thalamus, Hippocampus	Drowsiness, deep meditation	Yes
Alpha	8.0-12.0	Occipital	Calm, daydreaming	No
Mu	8.0-13.0	Sensorimotor Cortex	Attentive concentration	Yes
Beta	13.0-30.0	Symmetrical Frontal	High stimulation including anxiety	No

* Frequency ranges differ from source to source and should be considered guidelines.

Empirical evidence has shown that NT is efficacious in building greater attention in both ADHD diagnosed¹¹ and non-diagnosed individuals.¹¹ Further, the observed effect sizes compare to those of pharmacological treatments.¹ Despite a history of success (early records date to work on rabbits in 1875 by Caton⁸), it is not widely prescribed as a treatment and further, has had very little Educational research investigation. The first published work using NT in the classroom appeared in Pediatrics (March, 2014) by Steiner's research group at Tufts. The research was well-designed (n value, experimental design) and yielded benchmark results, supporting that NT holds potential as an effective tool in the classroom in building and sustaining student attention in the classroom.

Table 4: Summary of non-parametric (Spearman) correlation for pre-test post-test differences between attention and executive functioning for parent assessments

Source of Assessment	Inattention		Executive Functioning	
	Spearman Correlation	p-value	Spearman Correlation	p-value
Inattention	1	0	0.901	p < 0.05
Executive Functioning	0.901	p < 0.05	1	0

Discussion

- > The authors of this presentation view NT as a viable candidate for extensive empirical testing in the classroom. It is not seen as a panacea, but as a potential disruptive innovation and curricular supplement for the next generation classroom.

Given the accessibility of the technology and the vast potential NT holds in teaching students to become more effective at learning, it follows that MBE provides an ideal space to develop and critically review methodological/ethical considerations for implementation.

The results of this research support that NT can be effectively implemented in a classroom setting as a supplementary teaching technology used to build sustained attentional capacity. The authors would like to draw particular attention to the second set of results from this research – that building sustained attentional capacity via NT supports the growth of more effective classroom learning through improved planning and organizational skills.

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