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SPECIAL SECTION

QEEG-Guided Neurofeedback for Remediation of Dysgraphia

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Twenty-four individuals with refractory dysgraphia underwent a quantitative electroencephalogram (QEEG) to determine abnormalities of critical writing areas (left frontal and central). These abnormalities were trained with 5–10 sessions of neurofeedback to decrease excessive slow or fast activity in those areas. All 24 experienced significant improvement in handwriting. Two individuals who declined neurofeedback training did not improve over a similar time period. This approach appears to consistently improve handwriting in subjects with refractory dysgraphia.

Introduction

Dysgraphia refers to a disorder of written language expression in childhood. Writing difficulties have an adverse impact on academic performance in school as well as later on in adult life. The earmark is poorly legible, spontaneously written text. It may be associated with ADD, dyslexia (reading difficulty), or spelling difficulty. In other cases, reading and spelling may be preserved (Deuel, 1995).

Traditional approaches to remediation of dysgraphia include occupational therapy to improve sitting balance, reflex integration, proximal stability and hand strength, manipulation skills, motor accuracy, visual perceptual skills, and visual motor integration (Berninger & May, 2011). Many individuals continue to have writing difficulty despite such therapy.

Methods and Materials

In this report, we studied 24 right-handed individuals with persistent significant difficulty in producing legible handwriting despite prolonged educational and occupational therapy.

Each individual underwent a quantitative electoencephalography (QEEG) to evaluate abnormalities in cortical areas significant in handwriting (left frontal and central) (Rapp & Beeson, 2003). Excesses in slow wave (2–7 Hz or 8–12 Hz) or fast wave (21–30 Hz) activity were found in each case in left frontal and/or central areas. They then underwent 5–10 sessions of neurofeedback training aimed at normalizing each abnormal area. Neurofeedback was carried out using BrainMaster equipment (BrainMaster Technologies, Inc., Bedford, OH), referenced to the right ear, utilizing single channel training, with auto-thresholding, 20 minutes per session. Before and after neurofeedback, dysgraphia scoring was done to estimate the degree of improvement in handwriting. The scoring system used was a modification of the Checklist of Written Expression, Table 20–7, Penmanship (Suttler, 1992). The score was based on 5 criteria:

A. Spacing on page
B. Spacing of sentences
C. Spacing of words
D. Spacing of letters
E. Slant of letters

Each criterion was judged as 0 (poor), 1 (fair), or 2 (good), with a possible score of 0–10. Prior to training, total scores ranged from 3–6 (average = 5.4). Post-neurofeedback, scoring was repeated. Two individuals had a QEEG, but chose not to do neurofeedback. Each of them was scored as a 5 on the Checklist of Written Expression.

Results

Table 1 indicates the location of the abnormalities most likely responsible for the dysgraphia problem. Each abnormality was downtrained for five sessions each.

Table 2 indicates the effect of neurofeedback training on the subject's dysgraphia score. Overall, scores increased from 5.4 to 9.0 on average ($p < .001$), Wilcoxon test). No improvement was seen in the individuals who did not participate in neurofeedback. All of the patients who did not do neurofeedback self-reported no significant improvement.

Table 1. Relevant QEEG abnormalities in 24 individuals with dysgraphia	
Abnormality (absolute or relative power)	**N**
Excess delta (1–3 Hz) at C_3	5
Excess theta (1–3 Hz) at C_3	12
Excess alpha (8-12 Hz) at C_3	3
Excess high-frequency beta (21–30 Hz) at C_3	3
Excess delta (1–3 Hz) at F_3	2
Excess theta (4–7 Hz) at F_3	4
Excess alpha (8-12 Hz) at F_3	3
Excess high-frequency beta (21–30 Hz) F_3	3
Note. QEEG = quantitative electoencephalography	

Follow-up for 1–5 years indicated improvement was maintained in all of those subjects who did neurofeedback.

Table 3 indicates the result of neurofeedback training on the various comorbidities.

Discussion

Typical QEEG abnormalities in individuals with dysgraphia involved an excess of absolute or relative power of slow frequencies (2–7 Hz or 8–12 Hz) and/or fast frequencies (21–30 Hz) at F3 (left frontal region of the brain) and/or C3 (left central region of the brain). No consistent abnormalities of phase or coherence were noted. When the excess slow or fast frequencies were downtrained, significant improvement in handwriting occurred in all 24 individuals, resulting in scores in the normal range. This is the first study to show the efficacy of neurofeedback for remediating dysgraphia. The effect occurs rapidly (in 5–10 20-minute sessions) and appears to be long-lasting and probably permanent. The training also improved Attention Deficit Disorder in the 17 patients who also had this disorder. The training had no effect on other co-morbidities.

Table 2. Effect of neurofeedback training on dysgraphia score		
Pre-training score	**N**	**Post-training score (each individual)**
3	2	9, 9, 9
5	12	9, 9, 9, 10, 8, 9, 9, 9, 9, 9, 9, 9
6	10	9, 10, 9, 9, 9, 9, 9, 9, 9, 10
No training		
5	2	5, 5
Overall, scores increased from 5.4 to 9.0 on average ($p<.001$) Wilcoxon ranked sums and Mann-Whitney Utest. All the subjects improved significantly by self-report. Follow-up from 1–5 years indicates improvement has been maintained.		

Table 3. Common comorbidities of dysgraphic individuals and result of downtraining the abnormalities noted		
Comorbidity	**N**	**Result of Training at F_3 and/or C_3**
ADD	16	All remediated
Hyperactivity/impulsivity	9	Not remediated
Dyslexia	6	No improvement
Oppositional defiant disorder	5	No improvement
Depression	5	No improvement
Asperger's syndrome	3	No improvement
Auditory processing difficulty	3	No improvement

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