

EMG BIOFEEDBACK FOR HANDWRITING DISABILITIES: A CRITICAL EXAMINATION OF THE LITERATURE*

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Summary — A critical examination of the literature on the use of electromyographic (EMG) biofeedback for problems of handwriting is presented. Examined are the procedures, results and conclusions of clinical treatments of writer's cramp and the habilitation of writing. The major flaws in each study are discussed and conclusions drawn from the review are presented, the primary one being that EMG biofeedback of the muscles of the upper extremity has yet to be demonstrated as a treatment of choice for handwriting disabilities. The lack of a sound foundation of data is seen as the main reason for the paucity of investigations in this particular area. Suggestions for further work are offered.

The wide variety of problems to which EMG biofeedback has been applied is well known and has been summarized and critiqued by Basmajian (1978), Beatty and Legewie (1977), Blanchard and Young (1974), Ince, Leon and Christidis (1984, 1985), Olton and Noonberg (1980), Schwartz and Beatty (1977) and White and Tursky (1982) among others. One of the lesser known areas in which it has been utilized is the remediation of disorders of handwriting. Although attempts have been made, few studies have been conducted and recent years have witnessed a near abandonment of work in this field. The present article examines the clinical investigations in which EMG biofeedback has been employed as a treatment modality for handwriting disabilities and offers suggestions for resumption of study in this relatively neglected area.

THE TREATMENT OF WRITER'S CRAMP

Writer's cramp is defined as an occupational neurosis affecting chiefly the muscles of the thumb and two adjoining fingers induced by excessive use of the pen. It occurs in four main

forms — spastic, paralytic, neuralgic and tremulous (Stedman, 1976). This impairment is often painful and may result in complete inability to write. Because of the muscular activity required, EMG biofeedback appears to have at least surface validity for treating many cases. Most work in the area has been done with writer's cramp.

The initial systematic use of EMG biofeedback for this disorder was reported by Reavley (1975) who treated a man in his early thirties with a history of writing difficulty since his schooldays. The man's writing was characterized by several false starts followed by spikey, illegible scrawl with long pauses between words. He gripped the pen tightly, flexed his wrist and tried to write each word in a single movement. When under pressure he was unable to write.

Surface electrodes were placed on the outer aspect of the upper arm over the upper insertion of the brachialis muscle and the outer aspect of the midforearm, and in the first web space overlying the first dorsal interosseous muscle and 1 in. proximal to that point. No description is provided of the apparatus used

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nor of the feedback mechanism other than that it was auditory. The patient had to experiment with different postures of his upper extremity, changing pen grips and modifying the writing angle so as to arrive at the most relaxed muscle posture possible. Techniques employed, either singly or in combination, included relaxation training with galvanic skin response (GSR) feedback, EMG feedback and handwriting training under EMG feedback conditions. Therapy took place in 17 sessions over a 7-month period, much of the treatment being carried out at home by the patient. Within a single session of GSR feedback the patient became aware of the emotional component of his problem and began learning new self-awareness. With EMG biofeedback, he progressed towards "quick, effective and legible handwriting" and became "more adept" with exercise. A follow-up 8 months later showed that the handwriting improvements had been maintained and when a novel, anxiety arousing situation arose a few minutes of writing practice between four narrow lines prevented reversion.

While this may appear, on the surface, to be a successful treatment of writer's cramp with biofeedback, several issues militate against such a conclusion. Although the technique was first demonstrated to the patient and discussed in the clinic, a great deal of the treatment was conducted by him at home. One wonders precisely what he did there, especially in the absence of supervision. Did he follow all procedures correctly? Did he have the biofeedback equipment at home or only practice from what he recalled of his clinic sessions? It is somewhat remarkable that one session of GSR training led to an awareness of his emotional problems which were of many years' duration. Essentially, no data are presented on the results of treatment. Even though muscle output was used to determine electrode placement sites, the outputs of the critical muscles are not reported either for baseline or treatment conditions.

A more extensive clinical investigation was

conducted by Bindman and Tibbetts (1977) who treated six patients, aged 40–60, who had suffered from writer's cramp for a duration of from 3 months to 5 years. All were employed in positions requiring handwriting, e.g. bank manager, clerk, draftsman.

Surface electrodes were fixed over the tendons of the flexor muscles of the index finger and thumb and on the palmar surface of the hand. Feedback was auditory, consisting of increasing or decreasing sound intensity, depending upon muscle contraction or relaxation. Feedback was used aversively at first, the sound being very loud during hand spasms: this served to increase the spasms and muscle tension. The patients then had the task of writing while attempting to keep the sound volume as low as possible. Treatment was carried out over a 3–7-week period (the number of sessions, trials per session and rest periods per session are not reported). As the result of this therapy, one patient became symptom-free, one improved sufficiently to produce little or no disability at work, two improved but continued to have some work disability and two evidenced no change. These cases were followed for from 3 to 12 months post-treatment. One patient was found to have improved further, one had a relapse and four were unchanged from their status at the conclusion of their treatment sessions.

No details are provided by this article on any aspect of the methodology, apparatus, muscle activity or data analysis. No pre- or post-treatment handwriting samples are included for visual inspection of changes. It is curious that the recording electrodes were placed over the tendons of the finger flexors rather than over the muscles. The fact that only one patient became symptom-free and one improved significantly (one also showed a relapse at follow-up) does not lead to a conclusion that this was a successful approach.

Uchiyama, Lutterjohann and Shah (1977) worked with two males described only as A and B (no demographic data given) who had differing problems. A exhibited a high degree

of tension as soon as he took pen in hand but was able to write clearly. B showed tension only slightly above normal but his handwriting was illegible.

There were two phases to the treatment. In Phase 1, the patients were given biofeedback-assisted relaxation training, first as they kept their hands on a sheet of paper without holding a pen and second, during writing. In Phase 2, EMG activity was monitored during systematic desensitization. When EMG activity did not decrease, feedback was provided during relaxation intervals and then therapy proceeded as in Phase 1. Patient A was also given biofeedback training during *in vivo* desensitization. Training for A focussed on the dorsum of the right hand and for B, on the extensor muscles of the right upper extremity. Treatment was conducted over a 16–17-session period. It is surmised that the clinicians examined muscle activity and handwriting to determine progress but this is unclear from the report. Both patients exhibited a rapid decrease in muscle tension that was maintained over training. A was able to obtain a job and enjoy writing as a result of treatment. B made steady but variable progress and by the end of his treatment was able to produce legible handwriting. These patients were followed up 8 and 6 months later, respectively, and both were found to have normal handwriting. As in the previous study, too much information is missing here to enable a judgement to be made concerning the effectiveness of EMG biofeedback. For example, patient data, apparatus, electrode placements, muscles treated, feedback modality, baseline details, procedural details, data analysis and specifics on results are omitted. No handwriting samples are presented for either case. It also cannot be determined how much biofeedback and how much desensitization contributed to success.

The final study to appear in this field was conducted by Cottraux, Juenet and Collet (1983) who attempted to alleviate writer's cramp in 15 patients, nine of whom actually completed treatment. These received a num-

ber of therapeutic strategies, including EMG biofeedback alone, EMG biofeedback and/or relaxation or systematic desensitization and/or assertiveness training through role playing. This review will be restricted to the four patients who were treated solely with biofeedback. They were 29, 30, 37 and 45 years old, one female and three males, all of whom had some form of psychopathology and for whom chemotherapy and psychoanalysis had been unsuccessful. Their problems had a duration of 1–7 years.

Surface electrodes were attached to the skin of the dorsal surface of the forearm to monitor extensor muscles involved in the writer's cramp. Feedback consisted of an analog audio signal which the patients had to reduce in pitch by decreasing the tension of their muscles. Precisely how many sessions were conducted is difficult to determine since a table presented in the report lists them as being from 12 to 17 while the text states they were from 15 to 20. Also, it cannot be determined exactly how many trial and rest periods were given or what their length was, and the procedure is unclear as well. It seems, however, that the study proceeded as follows: patients were initially given the MMPI. Then, based upon a "behavioural analysis" (no information given on what this was), they received different treatments. The four patients who received EMG biofeedback first copied 10 lines of a standard text without biofeedback and were instructed to draw a vertical line when a cramp occurred which prevented writing. The number of cramps were recorded by both patient and clinician. Then, EMG biofeedback was given for 20-min sessions. The patients rested for 3 min and then were instructed to reduce the audio pitch of the feedback signal by decreasing muscle tension, presumably while writing. They were also told to repeat these therapy sessions twice daily in the absence of feedback. Cramps were recorded post- and during treatment and at follow-up. No statistical analyses were performed on the data and it seems that changes in performance were determined en-

tirely by a single independent evaluator who assessed improvement in cramps, percent of free handwriting improvement and quality of writing on three independent scales. These scales were then combined into a single scale of the means of the other three and viewed as global improvement scores. Outside the clinic, only self-reports were used as measures of change. Of the four EMG biofeedback cases, one rated a 4 on the global scale (normal handwriting) and three rated a 3 (markedly improved), which was better or as good as the patients receiving other forms of treatment. Follow-up was conducted 1-9 months later but no real data are presented for this.

The immediate question is, how did the clinicians know that the extensor muscles of the dorsal forearm were cramping? No EMG measures were obtained and no baseline data are reported for the outputs of these muscles, which are not specified. It is reported that "time spent" was recorded but what it was spent doing is not revealed. If, as it appears, the patients actually wrote for 20 min, this seems an excessively long time and would be likely to cause cramps in anyone. Patients were divided into the different treatments by a "behavioural analysis" but only the MMPI was used, meaning that the assignment to treatments was done on the basis of psychopathology not handwriting dysfunction. Also along this line, no comparisons were made of those who received EMG biofeedback with those who received another form of treatment, other than the sole number each was rated on the scale and no handwriting samples are presented for any treatment group. Additionally, to combine three scales, each measuring a different variable, into a single scale is meaningless for judging outcome. There seem to have been no controls employed in the work. Perhaps most important, these patients all had a significant psychopathology of which handwriting dysfunction was one behavioral consequence. It seems that they would have been better served by treatment of the basic

psychological problems than by focussing solely on their handwriting.

THE HABILITATION OF WRITING

Only one study has been reported in which attempts were made to teach writing skills with EMG biofeedback (Block, 1978). A 16-year-old boy, paraplegic from cerebral palsy, was taught to read and 30 months later was trained in handwriting. Concerning the latter, he exhibited mild upper extremity spasticity which resulted in limited finger dexterity. The clinical goals, basically, were to achieve handwriting which was as close to normal as possible in terms of writing speed and legibility through proper holding of a pen, correct arm and hand movements, correct paper positioning, correct finger positions and normal muscle activity.

Following a baseline evaluation period, a large number and variety of tasks were given to the boy to perform. Included were having the edge of his hand contact the table during writing, reduction of associated movements, particularly those of the contralateral upper extremity, increasing kinesthetic sensations and reduction of visual pen guidance. Feedback for correct behaviors was auditory tone signals and closed-circuit, amplified television. Also employed were EMG and "contact signal devices" but no description of these is provided. It does not appear that any electrodes were used to record muscle activity, rather strain gauges are reported as being on the patient's biceps brachii but how these were used is not known and no other muscles are mentioned as being involved in the treatment. Eight sessions were conducted initially and following an 18-month hiatus, 93 sessions. The treater examined handwriting samples, length of time required to complete certain writing tasks and movements of the patient's arm, hand and fingers to determine improvement. The time required for the boy to write the alphabet decreased from a pre-treatment mean of approximately 199 sec to an average of

about 37 sec during weeks 90–140. Legibility improved considerably and speed of writing improved in general. Spasticity of the boy's hand was "obviously" reduced, i.e. pen manipulation by his right hand was markedly superior to that by his left. This patient went on to college and did well. There was no systematic follow-up.

From the case report it is very difficult to ascertain exactly what the procedures were or how biofeedback played a meaningful role. None of the apparatus or feedback techniques were described and there is no way of determining how learning occurred. The use of strain gauges, presumably of the mercury-in-rubber type, to record muscle activity is highly suspect but since no indication is given of EMG output or how it was measured, it remains uncertain that this was, in fact, the method of recording and evaluation despite the author's claim that spasticity was reduced. (Concerning this latter point, it would not be unusual for someone who is right-handed to exhibit superior pen manipulation with that hand in comparison with the left hand.) How the various writing tasks received feedback when performed correctly or their relationship to the biofeedback is not reported. It should also be noted that the treatment took an exceptionally long time and how well the patient would have done had he only practiced on his own with some instruction but without specific biofeedback training over the years remains an unanswered speculation.

DISCUSSION AND CONCLUSIONS

Of fundamental concern is the issue of whether or not EMG biofeedback is a treatment of choice for handwriting disabilities. Subjects who receive biofeedback should be matched with those who do not, but only practice writing during the same time period. Feedback for correct behaviors needs to be compared with false feedback. Feedback should be provided not only for relaxation of

spastic and/or tremulous muscles but for the elimination of inappropriate muscle activity and increasing activity of weak musculature. It is of utmost importance to treat those muscles most appropriate for handwriting, those most likely to produce dysfunction and those actually measured as doing so. These might include the flexor carpi radialis and flexor carpi ulnaris (wrist flexion), the lumbricales (flexion of the metacarpophalangeal joints), the flexor digitorum superficialis (flexion of proximal and distal interphalangeal joints), the interossei palmaris (finger adduction), the flexor pollicis brevis and flexor pollicis longus (flexion of metacarpophalangeal joints of the thumb) and the opponens pollicis (thumb opposition). Other possible muscles to examine might be the pronator teres and pronator quadratus (forearm pronation), the extensor carpi radialis longus, extensor carpi radialis brevis and extensor carpi ulnaris (wrist extension), or the biceps brachii (elbow flexion) and triceps brachii (elbow extension), depending upon what is revealed during initial baseline measures. If the handwriting disorder is secondary to pain it appears more profitable to attempt pain alleviation or, at least, to determine the etiology of the pain. Should the pain be found to relate to muscle spasticity, the role of EMG biofeedback for reduction of output seems clear but should the pain result from improper arm or hand positioning or inappropriate pen grip, a simpler approach to correcting the problem may be called for. In cases where the handwriting difficulties are of psychogenic origin, biofeedback clearly would not be a method of choice; some form of behavior modification or other therapy would be warranted and this, too, must be determined at the outset.

Although the reasons for its near-demise are fairly obvious, it seems reasonable to study more closely the utility of EMG biofeedback in the treatment of handwriting dysfunction. Proper investigation techniques and complete reporting of all aspects of the data are indispensable.

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