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Case study

Increasing functional communication through relaxation training and neuromuscular feedback

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The following research examined the effects of behavioural relaxation training and biofeedback on ataxic tremor of an adult with acquired brain injury. The paticipant was taught relaxation techniques before biofeedback was introduced. Once he was proficient in relaxation, these skills were then used as a foundation for biofeedback training. Specific skills, facilitating the use of a letter board, were taught when the participant was able to relax the appropriate musculature to criterion. The results demonstrated that the participant learned how to significantly decrease the severity of tremor. As a result, he became more proficient at communicating via his letter board. Collateral effects were increased attempts at communication and fewer episodes of anger.

Introduction

Neuromuscular disorders involving the speech mechanism are common following acquired brain injury (ABI), even after recovery of primary language abilities [1]. A review of the literature points to the long-term impact of such disorders. Dysarthria has been observed to persist even years after treatment. For example, Thomson [2] found that 100% of a sample of 40 brain-injured adults continued to show signs of dysarthria 10–15 years post-injury.

Although the incidence and mechanisms of dysarthria are not well understood, in general the effects on speech synthesis depend on the locus of damage in the CNS [3]. For example, diffuse upper motor neuron damage causes pseudobulbar effects, whereas lesions in the brain stem produce ataxic effects. The functional impact on the speech mechanism includes nasal emission, hypernasality, breathiness, and consonant imprecision, distorted vowels, and harsh voice quality [4]. The relation between this chronic loss of functioning and subsequent behavioural episodes may be great [5]. Accordingly, examination of functional communicative alternatives is undoubtedly in order.

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Behavioural sequalae observed after an acquired brain injury are frequently observed. Many of these behavioural challenges can be linked to impediments in the realm of communication. Substantial issues with frustration can arise out of a desire to communicate effectively in the face of an inability to do so. Many times the neuromuscular disorders already described may prohibit the individual from conveying his most basic needs and desires. The issues arising from such problems can often lead to dramatic displays of unwanted behaviour and an overall decrement in functional communication abilities.

Functional communication training (FCT) is an intervention strategy that is widely applied in behavioural approaches to communication disorders [6, 7]. The primary intention of such intervention is to provide individuals with appropriate functional communication strategies that obviate the use of inappropriate behaviour as a way to communicate. Indeed, paving an avenue which allows access to preferred activities or other reinforcers has major behavioural advantages [6]. The old forms of unwanted behaviour are systematically extinguished, giving way to newly acquired functional alternatives.

Providing an effective means to communicate may be a particularly important step in the rehabilitation of individuals with ABI. The frustration experienced by individuals with dysarthria may be related to past experiences of effective discourse with others. This past history of communication is a sharp contrast to one's current abilities. The utilization of augmented communication devices as compensatory strategies may bridge the gap between functional utility and communicative intent [7].

The issues presented by dysarthria can be compounded when they are coupled with ataxia, another common residual of ABI. The presence of an ataxic tremor can impact the abilities of a person with a brain injury without noticeable deficits in their speech and language abilities, making performance of self-care tasks especially challenging. These obstacles are exacerbated when the tremor impacts one's ability not only to participate in given tasks, but to communicate with others. The participant in this study was unable to communicate some of his most basic needs, due to the limitation that his ataxic tremor placed on his ability to point to certain letters on his spell board.

The applicability of protocols targeting muscular relaxation appear relevant in such instances. The incorporation of relaxation procedures into a comprehensive package to address tremor disorders has proven beneficial to increase function and independence [8]. Previous findings, including electromyographic analysis of relaxed postures, indicate that these methods can be effective to assist individuals to achieve a relaxed state [9]. Lowered EMG levels were observed from the moment that the participants were placed in the relaxed postures, thus producing a rapid induction of a relaxed state. This state was then applied to a functional task that was improved as a result. The use of relaxed postures was also examined in a geriatric setting for the treatment of moderate-to-severe essential tremor. This case is noteworthy, due to the efficacy of the procedures and their utilization with Parkinsonian tremor. A 47–66% reduction in tremor severity was achieved [10]. Biofeedback has also been incorporated into comprehensive treatment programmes to address complications associated with thalamic stroke. Both pain and ataxic tremor can appear suddenly following thalamic stroke, significantly altering social and physical functioning [11]. Allen *et al.* [12] documented the use of EMG biofeedback in the treatment of a 9-year-old boy with communication difficulties arising from hyperfuntional dysphonia and vocal nodules. An interesting application of biofeedback technology was noted in the treatment of motor aprosodia with voice pitch biofeedback [13]. There have also been instances where these protocols have not been successful. Howe [14] investigated the teaching of a dichotomous response to a 37-year-old woman with severe brain damage using EMG biofeedback. He found that the woman was unable to learn to communicate using this method. This appears to be due to the severity of the woman's brain injury, as opposed to an indictment of the methods used. The successes noted in the literature present a strong case for their efficacy.

The current study employed the Behavioural Relaxation Scale (BRS) to assess the level of observable relaxation that was achieved by the participant [15]. A recent study has documented the validity of the BRS as a true indicator of relaxation [16]. Their findings support the use of the BRS as a valid, observable measure of an individual's relaxation response, as well as an effective tool to measure individual response to a variety of relaxation training protocols. The primary purpose of this study was to apply the principles of biofeedback and relaxation to the task of functional communication through the use of a letter board.

Method

Participant

The participant, Hugh, was a 21-year-old male who had sustained a brain injury as the result of an automobile–train collision. He experienced diffuse axonal injuries as a result of the accident. He also suffered a right humeral open fracture, right radial nerve laceration, splenic laceration with a splenectomy, and multiple other lacerations. After $\sim$ 3 months, he developed hydrocephalus and a shunt was put in place to address this. At the time of the study, he was utilizing a wheelchair for mobility with maximal assistance from staff for locomotion. Hemiparesis was noted on his right side.

He experienced a severe ataxic tremor over the entire length of his left arm during purposeful movement (kinetic tremor). His speech was severely dysarthric and he utilized a spellboard to communicate. Hugh could communicate some basic needs to others with yes/no responses, pointing, and some rudimentary speech, but he used the spellboard for more extensive interactions.

Setting

The study was carried out in a clinical office located on the grounds of a post acute rehabilitation centre. The office contained a 138×61 cm desk, two swivel chairs for the experimenters, and a recliner for the relaxation training.

Apparatus

Biofeedback training was conducted using an Autogen AT 33 biofeedback unit. The unit was equipped with an auditory and visual display of muscle tension displayed in microvolts. The AT 33 provided EMG readings based in intervals of 0.5–60 seconds. The sampling rate for the device was four readings per second, with an input impedance of 2400 $M\Omega$. The bandpass for the unit was 32–220 Hz (3 dB) with a common mode rejection of 140 dB. The test–retest reliability for the AT 33 was 90% for data taken over three consecutive trials. The participant's skin was cleansed with a vigorous alcohol rub prior to electrode placement. Disposable pregelled electrodes (3 cm silver/silver chloride) with adhesive pads were attached to the skin over the flexor and extensor carpi radialis muscles of the participant's left forearm. These points were determined from palpation and observing the points of maximum contraction when the wrist was flexed and extended. The same placements were used for each session. A reference electrode was placed over the ulna in midline between the two active electrodes.

Dependent measures

Clinical rating of tremor scale (CRTS)

The experimenters rated the amplitude of the participant's tremor in centimetres during movement tasks using a 0–10 scale [17]. A score of 0 indicated no tremor and a 10 was severe tremor. The tremor was rated in the left arm during utilization of the spelling board.

Behavioural relaxation scale (BRS)

A 10 item observational scale was utilized to assess the participant's relaxation level. During successive 1 minute intervals, the 10 items were scored as relaxed or unrelaxed. The first 30 seconds were used to monitor breathing frequency, the next 15 seconds to observe the other postures, and the last 15 seconds to record. A percentage score from 0–100 was derived from these observations.

EMG readings

Muscle tension levels were assessed through digital readings on the AT 33. These readings were expressed in microvolts (μV). Average microvolt readings were taken over the 10-minute relaxation periods and during spelling assessments.

Self-ratings

A self-rating was derived from a 0–7 Likert-type scale. These readings were taken at the beginning and end of each relaxation period. A score of 0 indicated extreme relaxation. A score of 7 denoted the presence of excessive tension and arousal.

Treatment phases

Baseline

The baseline segment of the study consisted of having the participant utilize the reclining chair to assume a 'relaxed state' with no prior training. Behavioural relaxation scores and EMG measures were taken during these 10-minute intervals. At the conclusion of the baseline relaxation interval, the participant's spell board was provided for the spelling tasks. He was instructed to spell out 'My name is Hugh' for three consecutive trials, while EMG measures were taken. (Other phrases were utilized on a random basis throughout all phases of the study). His view of the EMG digital display was obstructed during baseline to avoid possible inadvertent feedback.

(1) *Breathing*—Rate that is lower than that observed in baseline.
(2) *Quiet*—No vocalizations.
(3) *Body*—No trunk movement.
(4) *Head*—In midline with the body.
(5) *Eyes*—Closed with smooth eyelids.
(6) *Mouth*—Lips parted in the centre.
(7) *Throat*—No movement such as swallowing or vocalizations.
(8) *Shoulders*—Sloped and even with no movement.
(9) *Hands*—Curled in a 'clawlike' fashion, with fingers spread slightly apart.
(10) *Feet*—Pointed away from each other at a 90° angle.

Figure 1. BRS scoring criteria. The 10 relaxed behaviours that encompass BRT are detailed. One-minute intervals were divided so that the first 30 seconds of each minute was used to count the breathing rate, and the next 15 second period was used to observe the other nine behaviours. The last 15 seconds were then utilized to record on the data sheet.

Behavioural relaxation training

The participant was taught the 10 behaviours detailed in behavioural relaxation training (BRT) (see figure 1).

Training consisted of modelling and physical guidance for execution of each of the items on the BRS. Verbal feedback was then provided in the form of one-word descriptions of any body parts observed to be unrelaxed. Praise was provided related to body parts that were observed to be relaxed. The participant was then asked to sit still while the BRS was scored for five consecutive 1-minute intervals. At the end of this period, the participant was instructed to open his eyes and to provide a relaxation self-rating from 0–7.

The spelling task described above was then performed for three trials and EMG measures were recorded for each.

Biofeedback training

The participant was instructed to relax, employing the protocol described in the behavioural relaxation training phase. During the spelling tasks, auditory feedback was provided on muscle tension levels. An auditory tone was set to go off at the point when muscle tension levels exceeded a preset threshold. The threshold was based on the average microvolt levels observed during the behavioural relaxation phase. The threshold was then lowered in successive sessions, based on corresponding decreases in muscle activity.

Follow-up

A follow-up was performed 2 years after the last session during the biofeedback training phase. The procedures were identical to those utilized during the biofeedback training phase. However, there was no auditory feedback provided during this phase.

Reliability

The first author served as the primary observer throughout the study. Reliability data were taken on the behavioural relaxation scale and the clinical rating scale for tremor (CRTS). A graduate student in behaviour analysis and therapy, who was trained in scoring both the BRS and CRTS, served as the secondary observer.

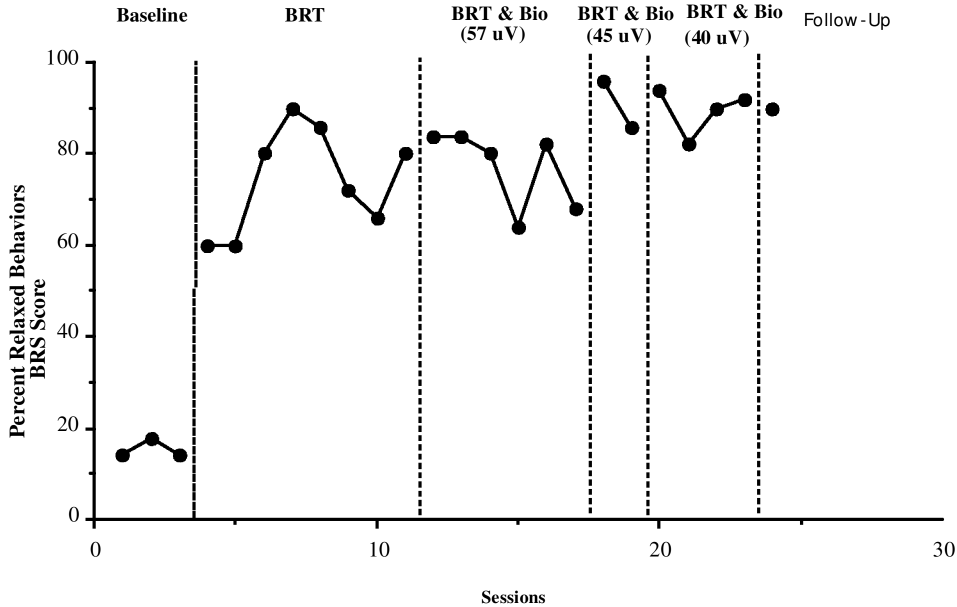

Figure 2. Behavioural relaxation scale scores. BRT = training in a recliner; Bio = EMG biofeedback (the threshold for each phase is in brackets); FU = follow-up. The circles represent the percentage of the 10 postures of behavioural relaxation training that the participant was able to demonstrate during the study (Source: Author).

Reliability data were obtained for over 85% of the clinical trials. The reliability score for the BRS was 94%, with a range of 86–100%. Reliability scores for the CRTS averaged 92%. Reliability was calculated with the following formula:

$$\frac{\text{per cent agreements}}{\text{per cent agreements} + \text{disagreements}} \times 100$$

Results

Figure 2 shows the participant's BRS scores throughout the study. The baseline average was 15.3% (SD = 2.3). Subsequent phases were as follows: BRT (M = 74.3%, SD = 11.5); BRT with the threshold set at 57 μV (M = 77%, SD = 8.7); BRT with threshold set at 45 μV (M = 89.5%, SD = 6.6); and BRT with threshold set at 40 μV (M = 91%, SD = 1.4). A follow-up was performed 2 years after the last session. A BRS score of 90% was obtained. With a limited amount of training in BRT, the participant reached 60% during the first training session. From that point on, performance generally increased over subsequent sessions, culminating to ~ 90% during the final phase. The data obtained during follow-up showed maintenance of these gains. An increase in BRS scores suggests that the participant became more proficient in relaxation skills over time.

Figure 3 indicates the participant's EMG values while spelling the sentence on his communication board. Each data point is an average of three consecutive measurements taken during a given session. The baseline average was 68.13 mV (SD = 3.3). Ensuing phases were as follows: BRT (M = 57.7 mV, SD = 3.6); BRT with the threshold set at 57 μV (M = 44.9 mV, SD = 4.2); BRT with thresh-

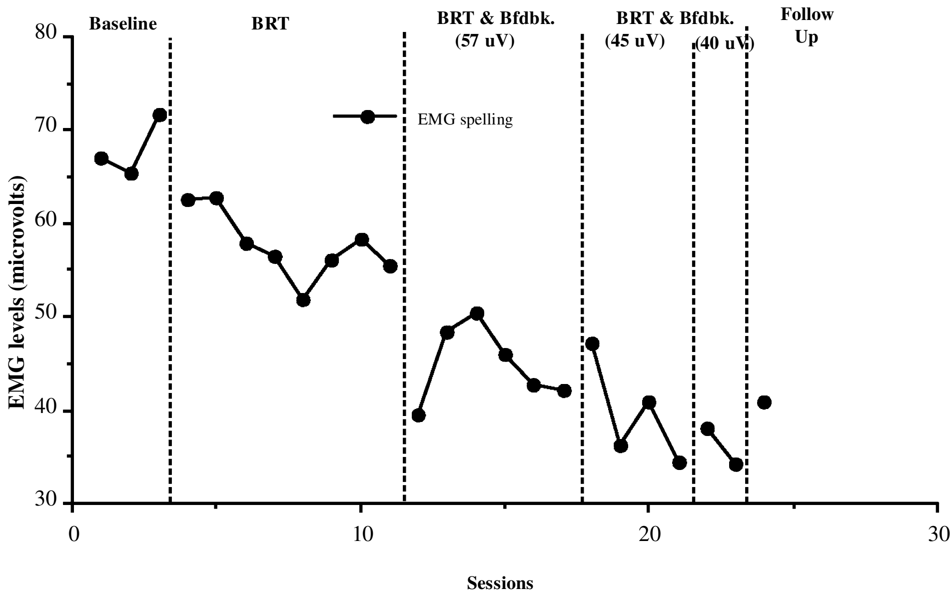

Figure 3. *Extensor/flexor EMG levels for a brain injury survivor with intention tremor. BRT = training in a recliner; Bio = EMG biofeedback (the threshold for each phase is in brackets); FU = follow-up. Each data point is an average of three consecutive measurements taken while spelling 'My name is Hugh' during a given session (Source: Author).*

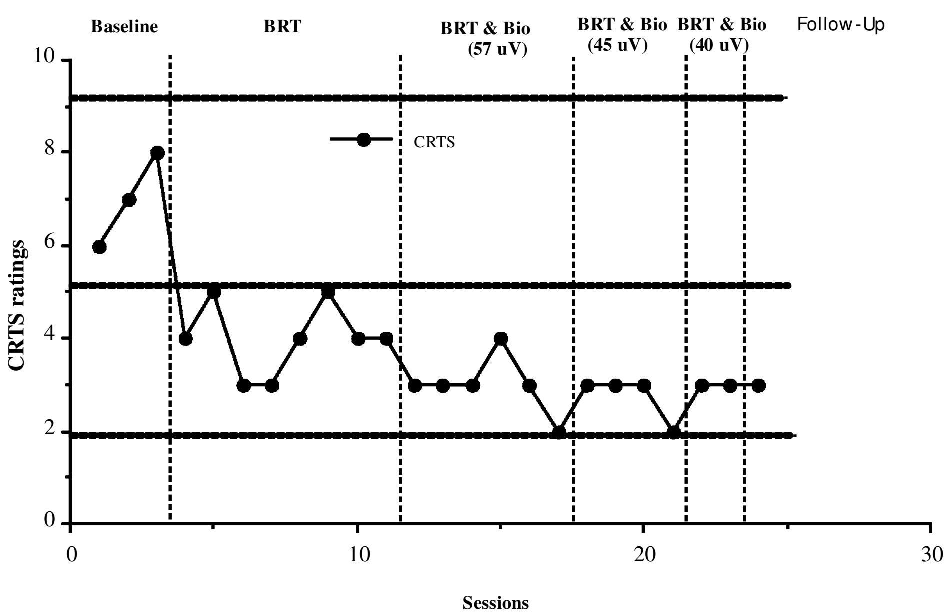

Figure 4. *Clinical rating of tremor severity (CRST). Tremor severity is expressed through amplitude of movement as measured in centimetres. BRT = training in a recliner; Bio = biofeedback training (the threshold for each phase is in brackets); FU = follow-up (Source: Author).*

old set at 45 μV ($M = 39.8$ mV, SD $= 5.7$); and BRT with threshold set at 40 μV ($M = 36.2$ mV, SD $= 2.6$). The value obtained at follow-up was 40.9 mV with a SD of 3.5.

Upon visual inspection, a trend in the data is apparent. BRT lowered levels to ~ 55 μV, and BRT coupled with biofeedback (threshold set at 57 μV), led to further drops of ~ 10 μV. Adjusting the threshold to a more stringent criterion, on average, led to a further decrease of approximately 5 μV. Levels stabilized at ~ 35 μV; lowering the threshold to 40 μV had little impact on his performance.

The data trends in figures 2 and 3 suggest that BRT and biofeedback have a synergistic affect. As BRS scores increase, EMG levels decrease. In other words, as the participant increases his skills in relaxation there appears to be a corresponding decrease in muscle tension.

Figure 4 shows clinical rating scores for tremor (CRTS), a functional measure of tremor severity. The baseline average was 7 (SD $= 1$). The subsequent phases were as follows: BRT ($M = 7$, SD $= 0.8$); BRT with the threshold set at 57 μV ($M = 3$, SD $= 0.6$); BRT with threshold set at 45 μV ($M = 2.8$, SD $= 0.5$); and BRT with threshold set at 40 μV ($M = 3$, SD $= 0$). The score observed during follow-up was 3.

During baseline, ratings ranged between ‘moderate’ and ‘extreme tremor/disability’. Conversely, ratings taken during the last three phases fell within ‘mild’ and ‘moderate tremor/disability’. These data suggest a clinically significant decrease in tremor that was maintained at the 2-year follow-up. Comparable to data trends seen previously, as the participant became more proficient in relaxation techniques, CRTS ratings markedly decreased.

Discussion

The outcome of the present study indicates the presence of a relationship between an increase in behavioural relaxation scores and a concomitant decrease in EMG levels. The participant was able to improve his performance with respect to the spelling task by learning a foundation of relaxation skills that he was able to apply when auditory feedback was provided concerning elevated muscle tension levels.

There were a series of other findings in the study that warrant further explanation. There was a noticeable fluctuation in resting EMG scores during the baseline phase of the study. A majority of these deviations can be attributed to some of the physical challenges that the participant experienced. He suffered from hemiparesis on his left side and had to be assisted in sitting upright after he was transferred to the recliner for relaxation. Some of the EMG fluctuations observed during this time could have been due to some bracing or other postural issues. There was also a marked increase in resting EMG scores noted when the participant had smoked a cigarette within 10 minutes of entering the session. The full effects of nicotine on one’s ability to relax has not been researched using the modalities employed in this study. It is evident that he was able to learn the postures of BRT very rapidly and, thus, could produce a better state of relaxation is manifested by his BRS scores. The issue of compliance with practice of the postures outside of the therapeutic environment is worthy of continued attention.

Proponents of any relaxation protocol specify that a main component of proficiency in the discipline is the amount of time spent rehearsing the relaxation procedure. This has been documented to be proportional to the gains observed through utilization of the procedure. Hugh experienced some generalized problems with programme compliance and follow through with requests. He had been directed to practice his relaxation training at least one-to-two times per day to increase his proficiency in sessions. Most of his self-reports provided in session indicated that he was unable to practice due to some of his cognitive deficits (e.g. forgetting). An area worthy of future research would be the level of influence that may be exerted by manipulating practice time and correlating this with treatment outcome. The provision of practice diaries would also be a useful endeavour. Another consideration that was serendipitously discovered was the limitations that some persons with ABI come into contact with regarding appropriate furniture to perform relaxation exercises in. Hugh was unable to utilize standard chairs around the residence for practice. Special considerations were made to compensate for some of his physical limitations, while still maintaining the integrity of the approach. Similar research has been done employing participants who were quite limited in their cognitive capacities as well [18].

Such studies could provide further information to the literature if the present results were extrapolated to use of more technologically advanced communication devices. The combination of the biofeedback technology with commonly used devices could benefit a number of individuals with acquired brain injuries who experience severe communicative problems.

Another point of relevance is the use of the CRTS for the brain injury population. This rating scale was found to be extremely sensitive to changes in tremor as they were manifested in *measurable* degrees of tremor. Such objective quantification of an otherwise subjective event provides clinicians with a practical device to track progress of ataxic tremor across a number of environments.

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