An Application of Electromyographic
Biofeedback to Aphasia/Apraxia Treatment

Malcolm R. McNeil
Thomas E. Prescott
Margaret L. Lemme

Veterans Administration Hospital
Denver, Colorado

The effects of induced muscle tension and anxiety on the efficiency of a variety of mental operations in normal adults has been demonstrated (Johnson, 1928; Duffy, 1932a; Stauffacher, 1937; Freeman, 1935; Courts, 1942; O'Brien, 1957; Meyer and Noble, 1958; Lovaas, 1960; Matarazzo, et al., 1955). Optimal cognitive efficiency is generally characterized by a specific pattern and range of values of physiological adjustments including muscle tension (McDaniel, 1970). Sainsbury and Gibson (1954) support the notion that anxiety is a physiological concomitant of increased neural activity of voluntary muscles. Other evidence supporting the continuous relationship between emotional states and learning in humans and animals is abundant (Wynne and Solomon, 1955; Schachter and Singer, 1962; Schachter, 1975). Several of the previously cited studies, illustrating the effects of stress on learning and information processing, have differed in the manner in which the stress was induced; however, Duffy (1932b) suggests an equivalence of muscle tension levels for both emotionally and physiologically induced stress. Although specific documentation for muscle tension and anxiety effects on aphasia is presently unavailable, it seems reasonable that these same, if not exaggerated, relationships might occur in brain-injured aphasic adults.

Several investigators have sought to explain various facets of learning and problem solving strategies in aphasic subjects (Tikofsky and Reynolds, 1962, 1963; Brookshire, 1969; Etlinger and Moffett, 1970). One general finding from these studies is that aphasic adults are capable of learning various speech and cognitive tasks, but the number of trials must be greatly increased over the number needed by normal subjects. Katz (1958) has hypothesized the lack of improvement in aphasic adults on goal directed tasks might be due to a reactivation of anxieties caused by continuous speaking failure. Brookshire (1972, 1973) has shown aphasic adult error responses generate effects which interfere with subsequent performance. Clinical observations would suggest that many patients with aphasia and/or apraxia of speech exhibit changed behavioral states, including anxiety and frustration, following error responses which may create a positive feedback loop whereby the patient's errors cause anxiety and frustration, which in turn cause additional errors. It seems obvious that understanding the processes underlying error response effects are highly important to the clinician treatment the aphasic adult.

The effects of presumed anxiety and muscle tension on aphasic adult performance has been studied to date, in three primary ways: Pharmaceutical agents (Linn and Stein, 1946; Linn, 1947; Billow, 1949; Bergman and Green, 1951; West and Stockel, 1965), progressive relaxation techniques (Marshall and Watts, 1976), and Transcendental Meditation (Allen, 1972). In summary, the results of drug therapy have generally proven ineffective or minimal and temporary at best. Progressive relaxation has been shown effective and T.M. seems to offer significant possibilities, although evidence is at present little more than speculative.

Another possibility for tension reduction in aphasic adults lies in the concept of biofeedback. The behavioral phenomenon underlying biofeedback suggests that individuals can regulate a variety of their own physiological functions, including skeletal muscle, once information is presented to them in a form that can be received (Brown, 1974). Successful regulation of such commonly considered physiologic functions as psychogalvanic skin response, blood pressure, and general muscle electrical activity have been reported (Brown, 1974). In recent years, electromyographic feedback systems have been incorparated into treatment programs for a variety of speech disorders including stuttering (Guitar, 1975; Hanna, et al., 1975) and dysarthria (Netsel and Cleeland, 1973). However, they have not been applied to the treatment of adults with aphasia or apraxia.

The purpose of this study was to incorporate electromyographic feedback into aphasia treatment in order to explore its effect on tension reduction and the effects of this tension reduction on selected speech and language tasks. This was accomplished by placing surface electrodes (Inman, et al., 1952; Lippold, 1952; Sainsbury and Gibson, 1954, and Sumitsuji, et al., 1967), which are equally as valid and reliable as needle electrodes (Komi and Buskirk, 1970, and Zuniga and Simons, 1970), on the frontalis muscle. Frontalis muscle placement has been shown to correlate better with general anxiety level than other skeletal muscles (Malmo and Smith, 1955; Balshan, 1962; Budzynski and Stoyva, 1969) and was selected in order to record electrical potentials (Mariacci, 1970; Chaffin, 1969 and Lindsley, 1935) as they varied with and without feedback. This electrical potential information was sent back to the subject for his use in modifying muscle tension.

Subjects

Four patients from the clinical population of the Speech Pathology Service at the Denver V.A. Hospital served as subjects. All subjects were aphasic and three of the four were also judged to have apraxia of speech. In addition, on regular clinical testing (for example, on the PICA or Revised Token Test) the subjects demonstrated an identifiable pattern whereby they would make an error, obviously be aware of the error, and perform less than optimally on several subsequent responses. This was judged to always be concurrent with expressed anger or frustration, which was not apparent on items performed to the patient's satisfaction (regardless of their accuracy). Other patient data can be found on Table 1.

Equipment

Figure 1 illustrates a schematic representation of the instrumentation used in this study. For specific electrical engineering on the BIFS Model I Unit, the reader should consult the article by Budzynski and Stoyva (1969).

Electrodes: The electrodes consisted of 3 surface electrodes, two recording and one ground (placed in the center of the two recording electrodes). The electrical potentials between the two recording points were measured with an integrated recorder. The electrodes were permanently

TABLE I

Subject Information

Subject	Age	Sex	Months Post Onset	O.A. PICA %ile	Months: Stable On PICA	Communication Disorder
1	68	M	13	89	3	Mild Aphasia Mod. Apraxia
2	65	M	10	58	3	Mild Dysarthria Mod. Aphasia Mod. Apraxia
3	55	M	27	98	5	Mild Literal Paraphasia
4	52	M	71	63	2	Mild Apraxia Mod. Aphasia

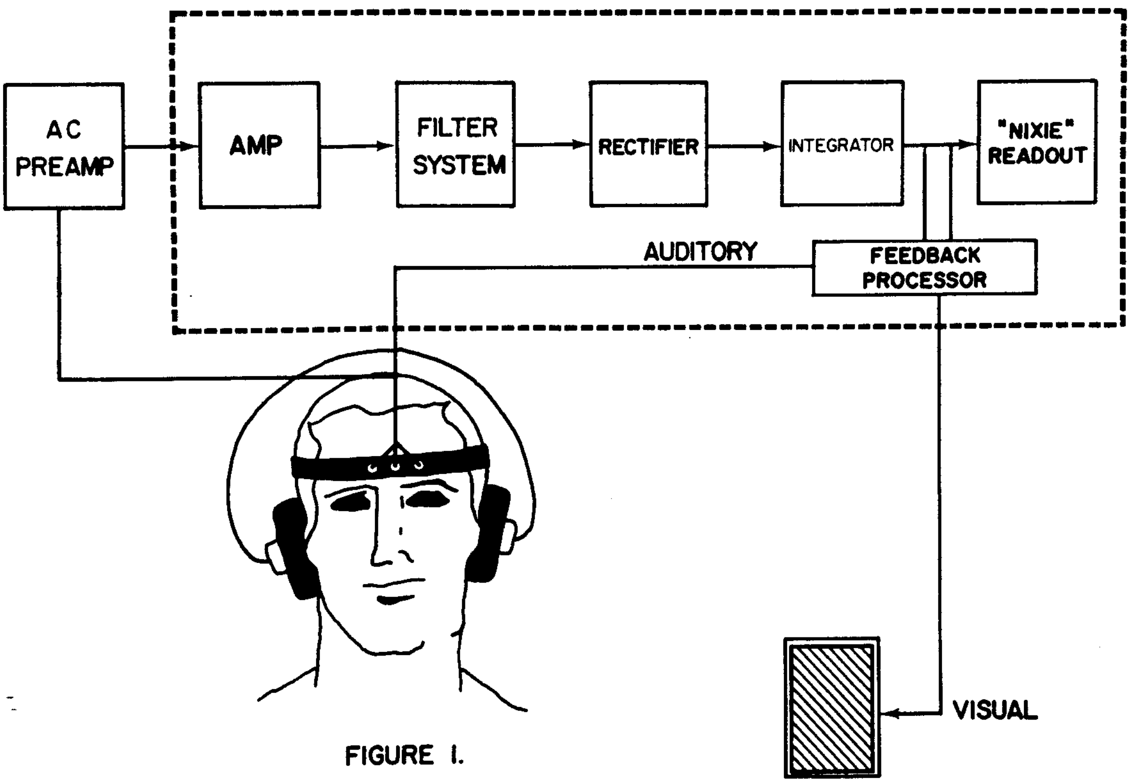

FIGURE I.
SCHEMATIC OF BIFS
EMG FEEDBACK UNIT

Figure 1. Schematic diagram of BIFS EMG feedback unit.

fixed to an adjustable head band and in this way were always placed an equal distance apart. They were placed over the frontalis muscle and the head band was adjusted to a comfortable level of tension. Each electrode cavity in the headband was filled with electrode paste (EKG paste) in order to insure a good contact and recording of electral potential from the muscle.

Preamplifier: The preamplifier was a Grass, Model PIS unit. For this study the low-filter cutoff was set at 100, the high filter cutoff was set at 10,000, and the gain was set at 1,000.

Integrated Recorder: The EMG integrated recorder was a BIFS, Model I unit. This unit sums and records the peak to peak amplitude voltages of each electrical wave produced by the muscle. It displays a numerical total of the voltages present during a given time interval via a Nixie Tube Apparatus.

All recording trials for all conditions were set at 32 seconds. The integrator circuit was set at the fast response time (rate of sampling of biopotentials) and the High Pass filter rolloff was set at 95 CPS.

Feedback: Two types (auditory and visual) of feedback reflecting electrical activity of the Frontalis muscle (and from other muscle activity, at least as low as the origins of the Deltoids, overflowing into the Frontalis) were initially evaluated. The auditory stimuli (presented at the patient's most comfortable loudness level) consisted of discrete clicks synchronized with every .01 registered on the Nixie Tube Recorder. This offered a direct, objective method of monitoring muscle tension. The second type of feedback was visually presented. It consisted of one small screen with three colored lights within (red, amber and green). Unlike the auditory stimuli, the sensitivity of the visual stimuli was under the direct control of the clinician by means of a sensitivity dial connected to the body of the BIFS unit. This allowed for continuous sensitivity selection, and a means of "challenging" the subject (his goal was to keep the light in the green) for purposes of lowering electrical activity and tension in the muscle. The visual monitor was placed at eye level approximately four feet in front of the subject.

Dependent Measures

The Porch Index of Communicative Ability (PICA) (Porch, 1967), the Revised Token Test (an expanded, multidimensionally scored version of DeRenzi and Vignolo's Token Test)(McNeil and Prescott, 1973), and a standard speech sample designed to elicit apraxia of speech (Wertz and Rosenbek, 1971) constituted the dependent measures. Each of these measures were administered in a random order to each subject immediately preceeding the training tasks and immediately following its completion. The entire battery was administered with the feedback apparatus connected but not providing feedback about muscle tension for both the pretest and the post-test conditions. The entire battery was also administered post-treatment while the subject monitored his tension levels with feedback. The two posttest conditions were randomly presented across subjects.

Treatment Procedures

The subjects sat in a comfortable chair with the three electrodes placed on the frontalis muscle and held in place by a head band. All biofeedback recordings and treatment procedures were conducted in a sound treated IAC booth. All subjects were seen five times per week for a total of 15 one-hour sessions.

Feedback Modality Selection: The initial three sessions of the therapeutic regime were devoted to establishing the most efficient modality or combination of modalities for administering feedback to the subject. Random assignments of auditory, visual and combined auditory-visual feedback conditions were administered.

Prior to every therapeutic session, two 32-second recordings were conducted with the electrodes connected to a dummy receiver for the purpose of measuring ambient electrical noise in the sound room. These measures were recorded but were not subsequently subtracted from the patient recordings, since intersession comparisons were not utilized. They were used only as a screening procedure to insure a normal range of pre-electrical activity within the room, and normal functioning of the equipment.

Cognitive and Speech Tasks: All subjects received the same progression of cognitive and speech tasks. However, the conditions of feedback and no feedback were randomly presented. A Baseline condition with both feedback and no feedback preceeded each session's cognitive or speech task. These and the no-feedback control condition for each task were administered to determine the effectiveness of raising tension level with a change of task and also to determine the effectiveness of tension reduction with feedback.

A series of cognitive and speech tasks were selected a priori on the basis of (1) having a sufficient number of tasks to allow relaxation under stressful conditions and (2) their probable hierarchial level of difficulty (a systematic desensitization type hierarchy). The tasks were always administered in the following general formats:

(1) Two baseline conditions, one with and one without feedback but with no task being performed were presented. Each condition consisted of three 32-second trials.

(2) A review of the previous session's task, with and without feedback, each consisting of three 32-second trials were then presented.

(3) A new task consisting of three 32-second trials without feedback, and six 32-second learning trials with feedback was then introduced. The learning tasks were administered in the following order, after the modality for feedback presentation was established. Response accuracy was not recorded.

A. Imagery Tasks: Each subject was instructed to imagine himself in a difficult but important speaking situation, and to concentrate on the frustrations or anger or other emotions he would experience. All subjects volunteered that the most difficult speaking situation they could imagine themselves in would be talking to their physicians because of the time pressures and lack of respect given them (the most vehement of the four patients about this point was himself a physician).

B. Recall Task: The subjects were instructed to recall as many state capitals as possible and then report them after each 32-second period. During this period, the task was to simultaneously recall and monitor his tension as indicated by the feedback he was receiving. The accuracy of recall was not recorded.

C. Silent Reading: THe subjects silently read a short factual story from the Reader's Digest and then answered questions about its content after the recording periods.

D. Hum Song: In an attempt to engage the vocal mechanism without content and with minimal articulatory activity, subjects hummed a familiar song while monitoring the feedback apparatus. The song was "Home on the Range".

E. Singing: Subjects next sang the song (Home on the Range) while monitoring the feedback given to them. This was included as an intermediary step between humming and actually engaging the Vocal mechanism in articulated speech.

F. Reading Aloud: The subjects read the same short story that they silently read on a previous task, while monitoring the feedback. This was included in this position in the hierarchy because it was felt that it would remove one step from the cog itive process of forumation since the content of what was to be said was provided.

G. Conversational Speech: The following topics were not hierarchially arranged but were consistently presented to each subject in order to provide an extended practice at this level and to prevent adaptation to a particular topic. All speech practice was continuously monitored with feedback.

Each subject expounded on whatever level he could about his favorite dog as well as about school days, work experiences, travel experiences, entertainment, and sports.

Analysis

Analysis of data was accomplished in several ways. A sign test was used (Siegel, 1956) to determine whether the subjects actually relaxed with feedback compared to without feedback. The reliability of three judges for rating the qualitative verbal measures was evaluated by a Kendall Coefficient of Concordance (Siegel, 1956). Differences between pre and posttest scores for these measures were subjected to a Chi Square analysis (Underwood, 1954). PICA overall and modality scores and Revised Token Test overall and total error scores were also analyzed by Chi Square. The expected value for these tests, however, were derived from the differences found between test and retest scores for the PICA and Revised Token Test original reliability data. Individual subject data were not subjected to statistical analysis.

Results

The Auditory Modality produced the greatest amount of relaxation in all four subjects ($P < .01$). The results were, however, somewhat inconsistent from day to day during the three day evaluative period. Modality preference was not always that which produced the best relaxation. The Auditory Modality was, however, used throughout the study.

All subjects were able to relax, as evidenced by lowered voltages, during periods of feedback as compared to baseline conditions without feedback. This occurred significantly ($P < .01$) for each subject, regardless of the task.

Analysis of the verbal qualitative measures was abandoned after one subject's speech sample was rated. Although the interjudge reliability was relatively high ($W = .71$) the subject performed randomly across tasks and across speech and language dimensions. No patterns or explanations for the obtained results were evident.

Figure 2 shows the overall results for all four subjects on the PICA. The subjects as a group improved from PICA pretest scores ($\bar{x}$ = 78%ile to $\bar{x}$ = 83%ile points). This improvement was equal for both posttest conditions (with and without feedback). However, this improvement was nonsignificant at the .05 level of confidence.

Modality performance is also illustrated in this figure. Both Gestural performance posttest conditions significantly improved ($P < .05$) from pretest scores (79%ile to 87%ile without and 88%ile with feedback).

Posttest verbal performance conditions for this group of four subjects were also significantly ($P < .05$) better than pretest. The subjects performed better without feedback than with it, although both posttest conditions were better than pretest (Pretest = 58%ile, Posttest = 62%ile without, 60%ile with).

Graphic performance improved from pretest performance (84%ile) to posttest without feedback (87%ile) and posttest with feedback (86%ile). This improvement, however, was not significant at the .05 level of confidence.

Figure 3 illustrates the overall results for the Revised Token Test. Group performance significantly increased from pretest scores ($P < .05$) to posttest scores. As can be seen, this significance can probably be attributed to the increase in posttest with feedback condition (55%ile) rather than the posttest without condition (49%ile) since the pretest percentile was 47.

The total number of errors on the Revised Token Test decreased from 62.5 on the pretest to 55 and 53.8 on the posttest without and with feedback, respectively. Neither of these differences were significant at the .05 level of confidence.

In general, it can be summarized that individuals were not consistent in their improvement across categories or across the feedback and no feedback posttest conditions. Eight-one percent of the posttests were improved over pretests. Seventy-nine percent of the posttest performances without feedback were improved, and eight-seven percent of the posttest with feedback scores were improved over pretest. Individual subject performances are represented in Figures 4 through 9.

Subjectively, subjects appeared to perform the therapeutic tasks better (e.g., with less struggle, more fluency, less effortful productions, more recall and faster reading rate) when receiving feedback. This was inconsistent and no systematic account was taken of these response differences.

In every case, a family member initiated a contact with the speech pathology service, indicating a dramatic positive change in the patient's communicative and social behaviors. This however could have been due to the fact that family members were aware that the subjects were participating in the study.

Summary

In summary, then, all subjects relaxed with our biofeedback procedures. In addition, group data for the combined posttest feedback conditions for the PICA and RTT demonstrated a significant ($P < .05$) increase in performance on PICA gestural and verbal subtests as well as the Revised Token Test overall. Observationally, the subjects performed better while receiving feedback and family members reported both communicative and social improvements. Individuals were inconsistent across tasks, which may reflect the nature of their involvement, rather than inconsistencies in their

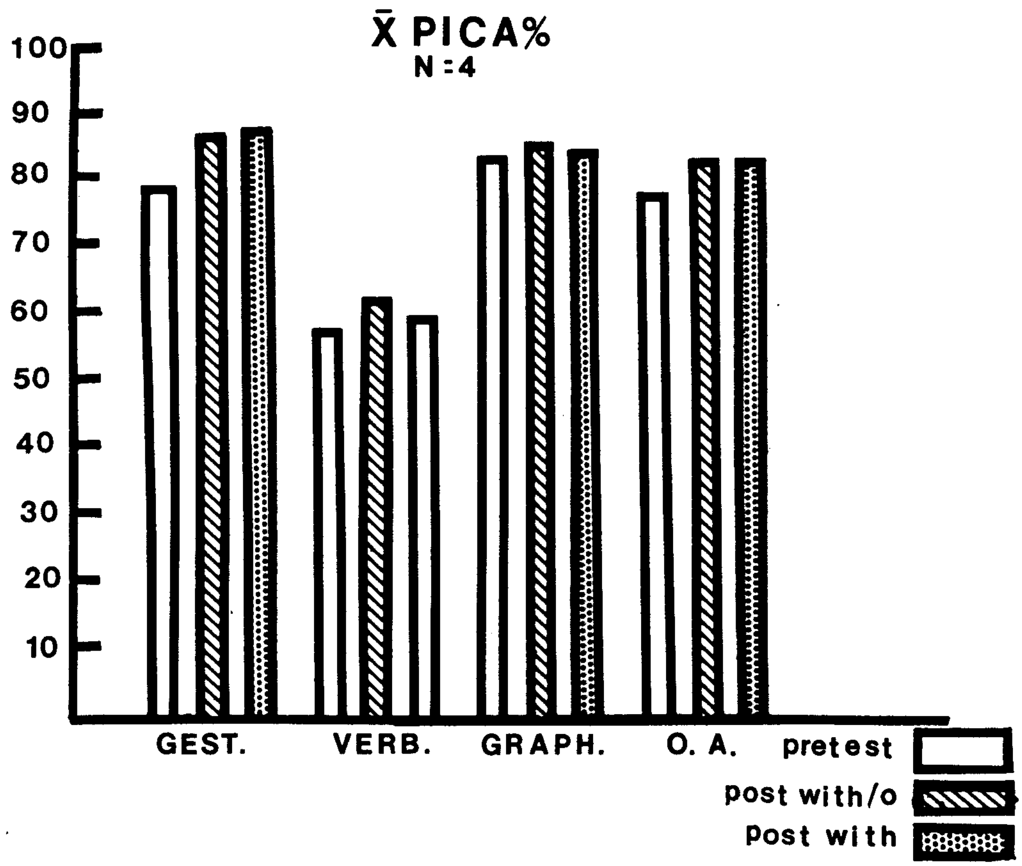

Figure 2. PICA overall percentiles.

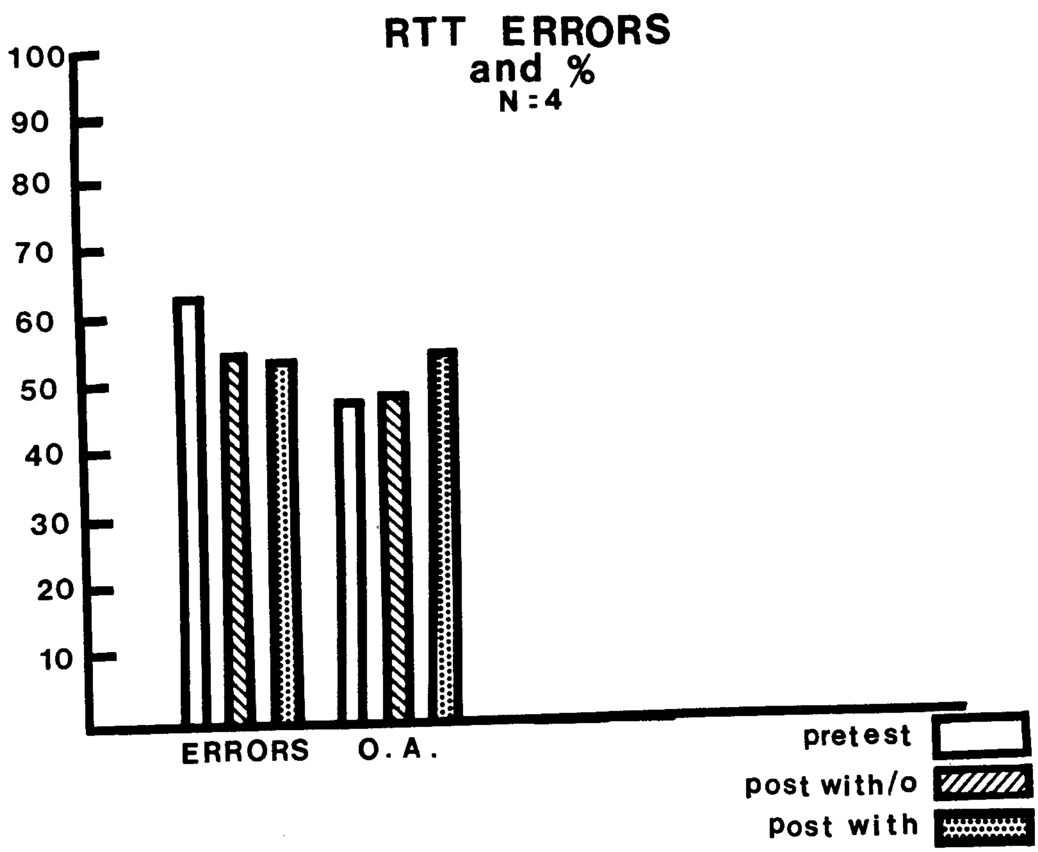

Figure 3. Revised token test overall percentiles.

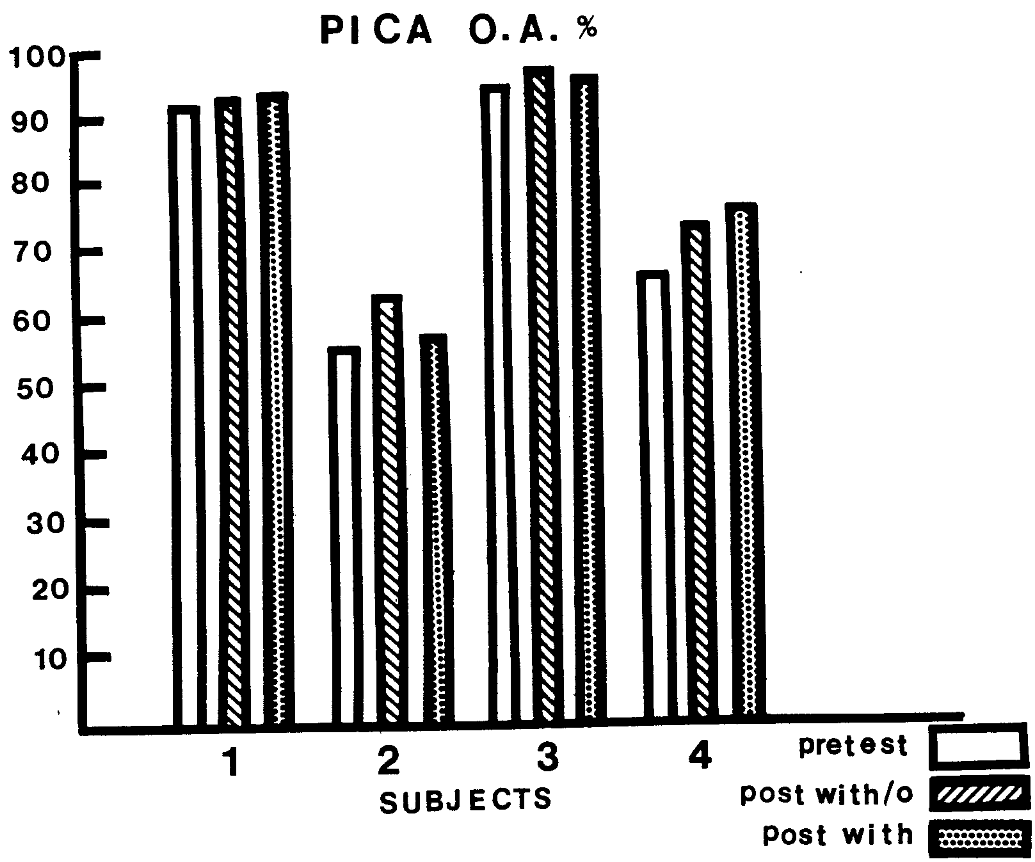

Figure 4. Test results for four subjects.

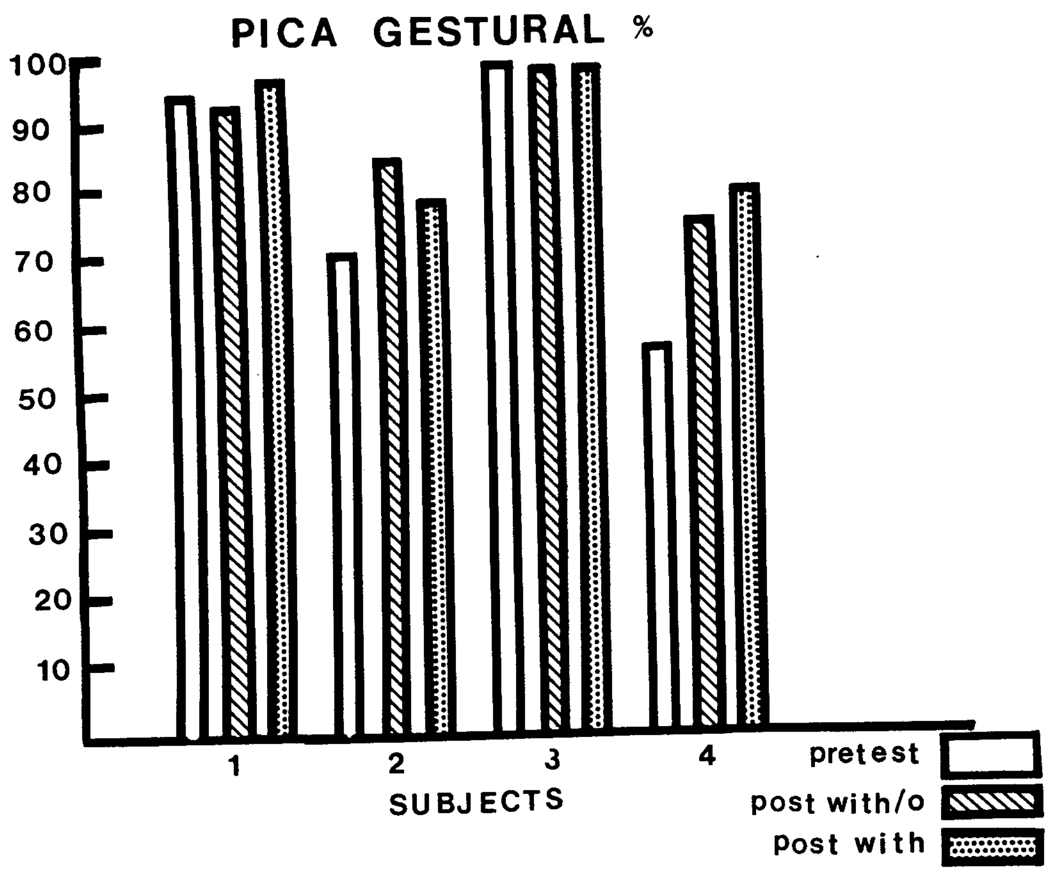

Figure 5. Test results for four subjects.

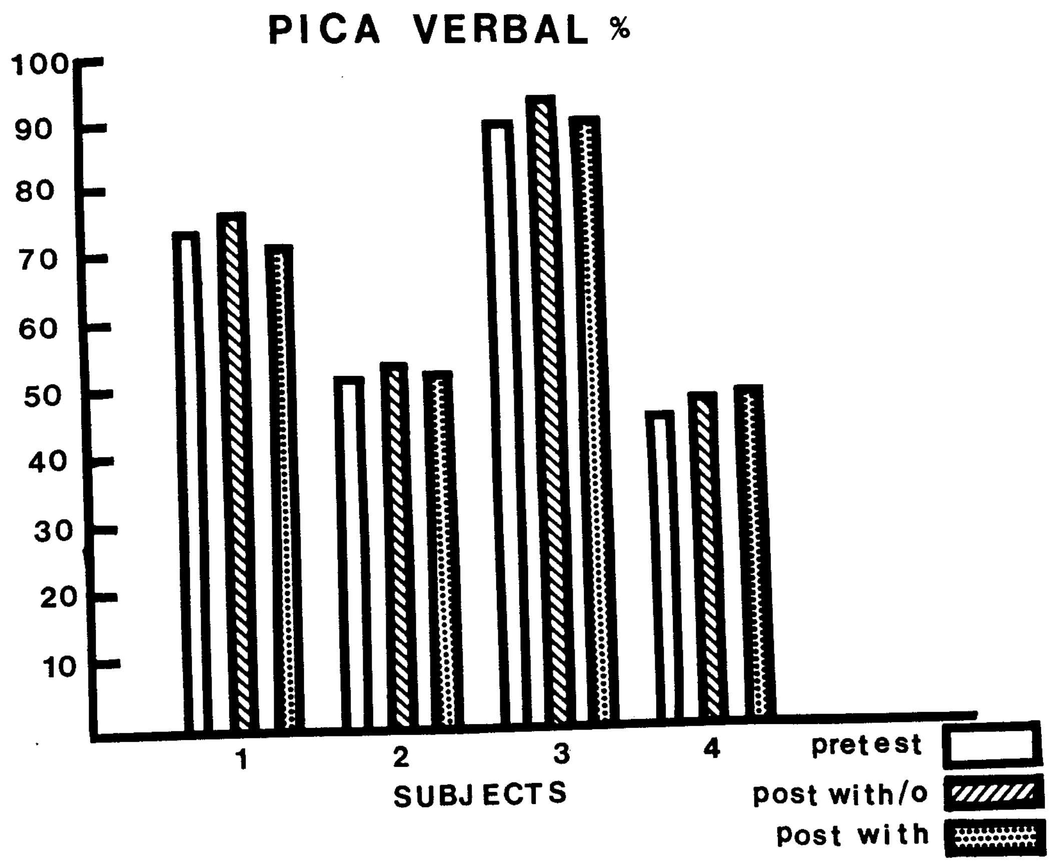

Figure 6. Test results for four subjects.

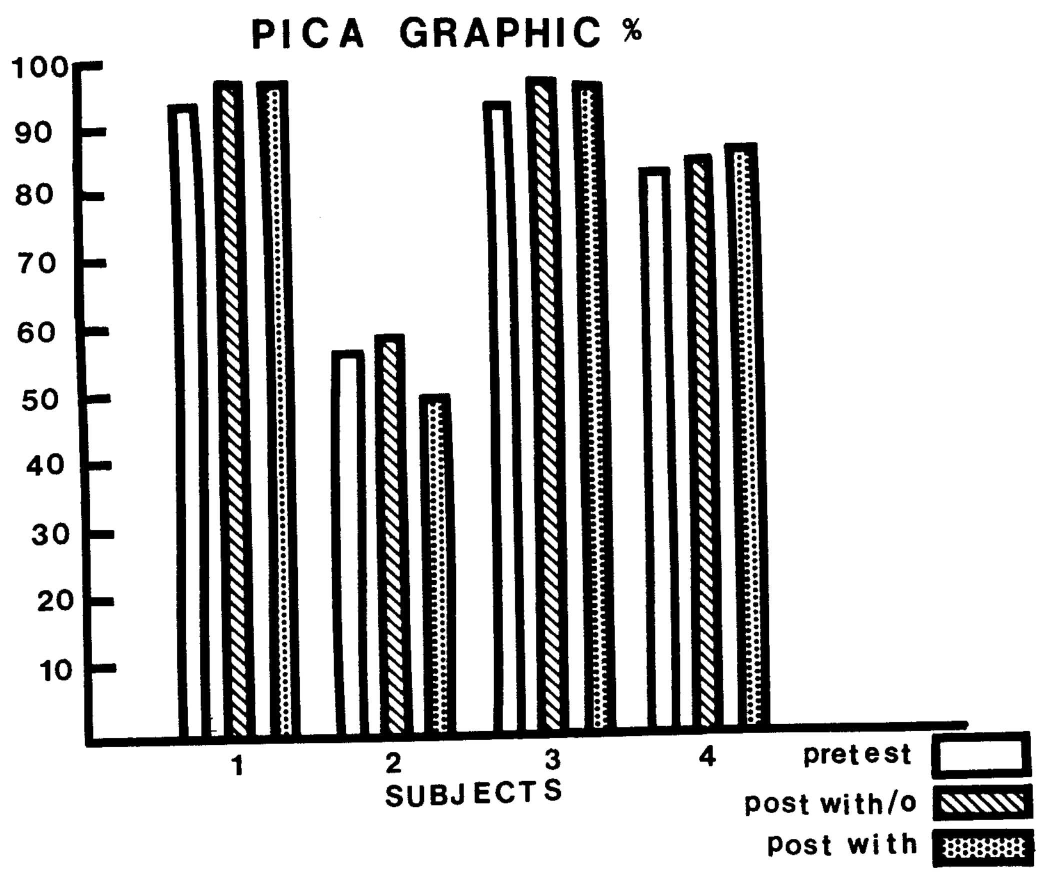

Figure 7. Test results for four subjects.

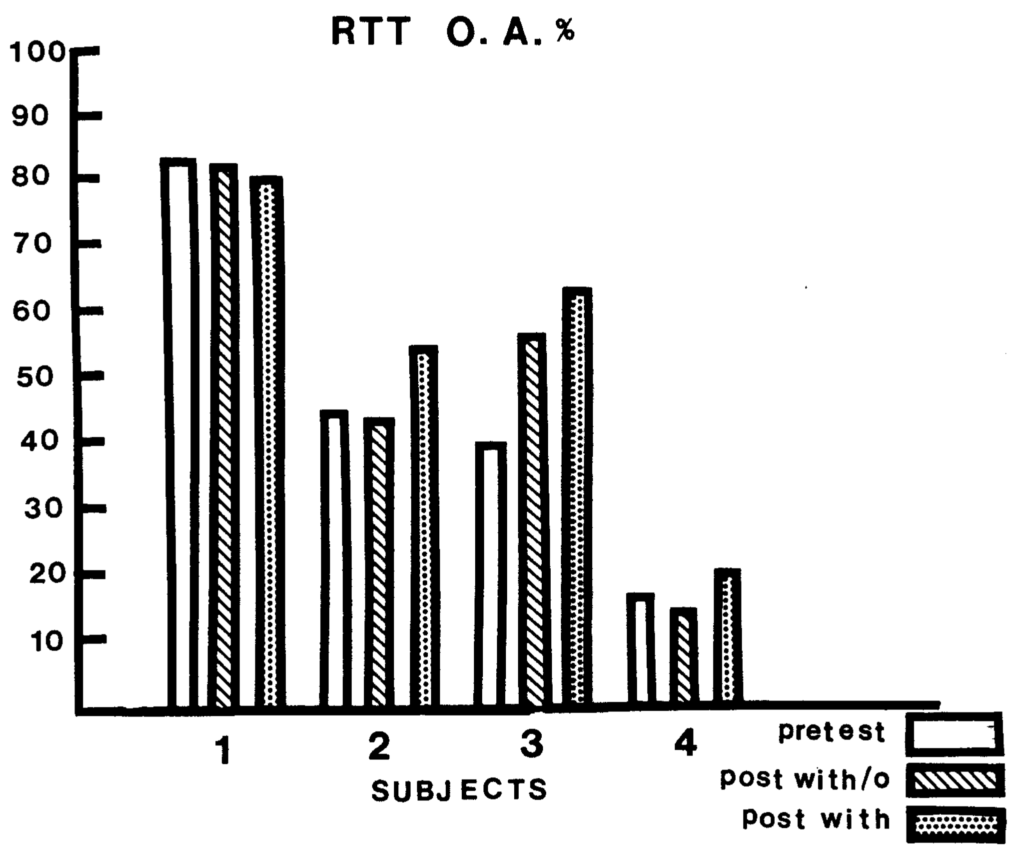

Figure 8. Test results for four subjects.

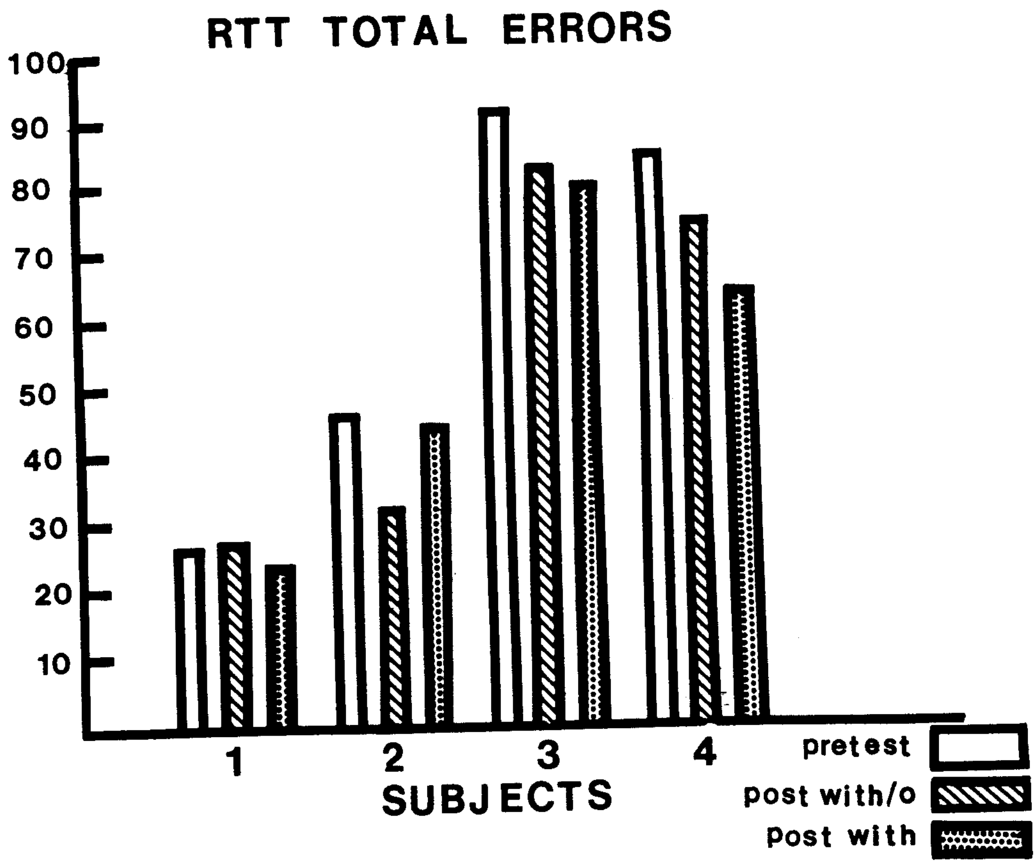

Figure 9. Test results for four subjects.

performance. Due to the small number of subjects studied, these data must be regarded as preliminary. However, we interpret them as evidence of improved performance with relaxation, and evidence of a need for further study.

Audience Discussion

Q - Was any information given to the subjects about what was expected of them in terms of relaxing, thereby enhancing the possibility of placebo effect?

A - The patients were told only that they were entering an experiment whereby we would teach them to use the biofeedback apparatus and measure any possible changes that it might have on their speech.

The results between the feedback and no feedback conditions suggest that the subjects did perform differently while receiving feedback (both electromygraphically and speechwise). However, since no control group received a placebo treatment, this remains a remote possibility.

Q - Is the Feedback unit used in this study commercially available?

A - Yes, this type of EMG Unit is available from several manufacturers. In addition, thermal, tactile, and several other devices are available for alternate modality, pickup and feedback. Most pyschology departments at hospitals and universities are equipped and knowledgeable about biofeedback apparatus.

Q - Do you see any application of this technique to the study of the effects of manipulating other variables on input processes, such as those discussed in the takeout paper by Dr. Darley?

A - Yes. For example, the effects of manipulating intensity on physiological functions such as muscular tension could be determined with this equipment. In the same way, training could then be given to either increase or decrease this tension to an optimal level for processing the information.

ACKNOWLEDGEMENTS

Much of the general outline for the review of literature is based on the work from William Cheverett's Dissertation, from the University of Denver, 1973. We wish to express our appreciation for his permission to use it.

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