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EFFICACY OF MIRROR TRAINING AND EMG FEEDBACK ON UNILATERAL FACIAL PARESIS

BY

SHARON PATRICIA EVELYN

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THE UNDERSIGNED CERTIFY THAT THEY HAVE READ, AND RECOMMENDED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH FOR ACCEPTANCE, A THESIS ENTITLED **EFFICACY OF MIRROR TRAINING AND EMG FEEDBACK ON UNILATERAL FACIAL PARESIS**

SUBMITTED BY **SHARON PATRICIA EVELYN**

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF **MASTER OF SCIENCE**

IN **SPEECH-LANGUAGE PATHOLOGY**

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ABSTRACT

The effects of two methods of facial muscle retraining were investigated via a single-subject, multiple-baseline, interaction design across two behaviors in four subjects. The subjects exhibited unilateral facial paresis subsequent to acoustic neuroma excision and received five 1-hour treatment sessions weekly across a 12 week span. Two perioral muscle groups were targeted for training: zygomatic group and labial levator group. Dependent variables used to monitor effects of training were graphic displays of surface electromyographic (EMG) data associated with each subject's performance of "smile" and "snarl" probe gestures, and full face photographs. The independent variable was facial muscle treatment with two levels: (1) facial exercise with visual feedback from a mirror and (2) facial exercise with visual feedback not only from the mirror but also from computer display of surface facial electromyograms. Graphic analysis and visual inspection were used to document changes in time series data across baseline and treatment phases of the investigation. Spearman Rank-Order correlations were used to examine the relationship between the accuracy of facial electromyogram "ramp functions" and the symmetry ratings of corresponding photographs for the "smile" and "snarl" gestures. The relationship between photograph symmetry ratings and the amplitude ratio of the corresponding bilateral EMG records was examined in a similar manner.

Results suggest that improvements in both "ramp function" accuracy and symmetry ratings were exhibited for one or both target behaviors across all subjects during the application of mirror training compared

to baseline, during the application of "mirror-plus-EMG" training compared to baseline or during the application of "mirror-plus-EMG" training compared to mirror training. Hence, this investigation showed an overall treatment effect compared to the baseline data for all subjects. The data do not support, however, the conclusion that one treatment paradigm is more potent than another. Results of correlations between "ramp function" accuracy and symmetry ratings of corresponding photographs and between amplitude ratios of bilateral facial electromyograms and symmetry ratings of corresponding photographs revealed that the variables in question were only weakly, and sometimes inversely related.

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CHAPTER I. LITERATURE REVIEW

To date few published accounts of treatments that utilize both mirror and EMG feedback in the rehabilitation of facial paralysis/paresis have varied systematically the application of either method. In addition, there is no evidence that a correspondence exists between visually symmetrical voluntary facial gestures and visual analogs of facial EMG signals with bilaterally equivalent amplitudes. Therefore, the purpose of this investigation was to generate empirical data regarding the relative effectiveness of mirror training alone, versus mirror training in conjunction with feedback about facial muscle EMG and to investigate the relationship between visually symmetrical facial gestures and corresponding surface electromyograms, as well as the relationship between visually symmetrical facial gestures and corresponding amplitude ratios of bilateral facial electromyograms.

Etiology, Incidence and Nature of Facial Paralysis/Paresis

The altered cosmetic and functional features associated with neuromuscular damage, particularly those of the facial nerve, are frequently unacceptable to the self-concept of the person who has suffered VIIth cranial nerve injury. Regardless of cause, loss of facial mobility is devastating (Booker, Rubow & Coleman, 1969). The patient's ability to voluntarily control, and communicate nonverbally with, the impaired mimetic muscles never recovers fully to the pre-trauma level.

Katusic, Beard, Wiederholt, Bergstralh, and Kurland (1986) and Markley (1978) indicate that mouth and cheek flaccidity may be associated with facial paresis/paralysis, thus affecting the patient's ability to speak and impairing continence of food and saliva during feeding and swallowing. Additional problems, including incomplete voluntary eyelid closure, vestibular dysfunction, auditory deficits (diminished or absent hearing), dental liabilities, or some combination thereof, can accompany the emotional devastation of facial paralysis/paresis.

Table 1 outlines causes of facial nerve disorders as diagnosed by May (1986) over a 20 year period (1963-1983).

Table 1. Causes of Facial Nerve Disorders Seen by May (1986) Across a 20-year Period

CAUSE	# OF PATIENTS	(%)
Bell's Palsy	895	57
Trauma	268	17
Herpes zoster cephalicus	117	7
Tumor	91	6
Infection	70	4
Birth (congenital & acquired)	48	3
Hemifacial spasm	28	2
Central nervous system (axial) disease	18	1
Other	30	2
Questionable	10	1
TOTAL	1575	100%

Published figures reported by Katusic et al. (1986) indicate that incidence rates for Bell's palsy range from 8 to 240 per 100,000. Although a significant number of patients afflicted with Bell's palsy spontaneously recover, from 14 to 35% of Bell's palsy victims are left with debilitating facial dysfunction (Jankel, 1978; May, 1986; May, Klein, & Taylor, 1985; Peitersen, 1982). May, Croxson and Klein (1989) report that the most severely affected region of the face is generally around the eye. In their opinion the region surrounding the mouth either recovers spontaneously or is infrequently affected severely enough to require surgical reanimation.

Another major cause of flaccid facial paresis, acoustic neuroma, is a benign neoplasm of the eighth cranial nerve sheath. The tumor may begin in the cerebellopontine angle or in the internal auditory meatus and must be surgically removed. Both the facial (CN VII) and acoustic (CN VIII) nerves share the internal auditory meatus and course together in the facial canal through the petrous portion of the temporal bone (Zemlin, 1981). Facial paresis may occur prior to surgical excision of the tumor because the facial nerve is stretched and compressed as the acoustic neuroma grows, widens the internal auditory canal and expands into the cerebellopontine angle. Furthermore, the facial nerve may sometimes be invaded by the acoustic tumor (May, 1986; Moffat, Croxson, Baguley & Hardy, 1989). The predominant surgical problem, therefore, lies in the technical difficulties associated with dissociating the facial nerve from the acoustic neuroma (Croxson, Moffat, Hardy & Baguley, 1989). In order to completely remove the acoustic tumor, the facial nerve may need to be resected (May, 1986). Moffat et al. (1989) report that even when the facial nerve remains anatomically preserved following surgery, 40-90% of the patients may exhibit acute signs of surgical trauma, including complete clinical unilateral facial paralysis. According to Moffat et al., "the integrity of the facial nerve after surgery is not necessarily an accurate indicator of final functional facial outcome" (1989, p. 172).

Implications for Functional Recovery of Facial Motor Control

Sunderland (1968, 1981) suggests that there are five degrees of nerve injury with the first degree being the least severe. First degree nerve injuries, generally involving a minor compression of the nerve, spontaneously recover within a short period of time. Voluntary motor control recovered after second or third degree nerve injuries may need neuromuscular retraining. Wallerian degeneration (degeneration of the nerve distal to the site of damage), present in second degree nerve injuries, is often followed by regeneration after a period of time. In third degree nerve injuries, involving considerable Wallerian degeneration, the endoneural sheath which surrounds each nerve fiber is irreparably denatured. Regeneration is incomplete and imperfect in third degree injuries, or worse, because the damaged axons "are no longer confined to the endoneural tubes which originally contained them" (Sunderland, 1981, pp. 22). Neural regrowth after such nerve injuries may involve cross-shunting and other aberrant regenerative patterns that may result in a motor recruitment disorder, mass movement, synkinesis or some combination thereof. Corral-Romero and Bustamante-Balcarcel (1982) note that if mass movement is due to "non-specific" regeneration of damaged axons, the patient should be able to learn, using biofeedback, to control this defect. Hence, neuromuscular retraining may be beneficial in the rehabilitation of third degree nerve injuries. Fourth and fifth degree nerve injuries indicate that surgical rehabilitation is necessary. Fourth degree nerve injuries involve severe nerve mangling. The disorganized tissue must be removed and the nerve ends prepared for possible reconnection. The most severe nerve injury, fifth degree, indicates that the nerve has been completely severed, therefore, dynamic or static surgical rehabilitation of the facial nerve or the facial muscles is necessary. Fourth and fifth degree nerve injuries that are surgically converted to third degree injuries may be succeeded by neuromuscular retraining (Balliet, 1989).

Rehabilitation Options for Facial Nerve Damage

Surgical Techniques

Surgical rehabilitative procedures are often necessary when inadequate cosmetic and/or functional results follow insult or trauma to the facial nerve (CN VII) (Moffat et al., 1989). Although there are many surgical restoration techniques available today for persons who have suffered traumatic damage to the facial nerve, including nerve transfers, or anastamoses, nerve grafting, muscle transfers, facial slings and integument procedures, the functional results of these techniques are subject to reorganizational phenomena within the central nervous system (i.e., facial nucleus reorganization) and peripheral, neuromuscular regenerative phenomena (Bratzlavsky & vander Eecken, 1977; May, 1986; Montserrat & Benito, 1988). As a result, the involved side of the face may not be restored to a normally functioning level, and the patient may exhibit residual effects, including abnormal resting tone, voluntary weakness, dyskinesis, synkinesis, mass action or some combination thereof (Balliet, 1985).

Although "patients with facial paralysis do not always attain satisfactory recovery through surgery or medical treatment" (Corral-Romero & Bustamante-Balcarcel, 1982, p.166), Markley (1978) points out that "the final goal of reconstructive surgery in facial paralysis is restoration of normalcy" (pp. 225). Not only are normalcy and symmetry of the face during rest and in motion goals for surgical rehabilitation, they are also desirable goals for facial muscle retraining. Unfortunately, complete restoration of facial functioning is not yet a realistic goal. "Once facial nerve function is altered and regeneration occurs, the sophisticated, orchestrated movements that comprise normal facial language can never be [fully] restored" (May et al., 1989, p.225). Evidence in the literature, however, suggests that improvements can be made beyond those achieved by spontaneous recovery or reconstructive surgery alone. There are two such approaches, electrophysiological and behavioral.

Electrophysiological Techniques

Efficacy of electrotherapy as a method of treatment for denervated muscles remains controversial. Although some evidence suggests that electrical stimulation is effective in preventing and reversing muscle atrophy, thereby permitting reinnervation to occur naturally (Clemmesen & Schinhof, 1947; Gutmann & Guttmann, 1942; Jansen, Lomo, Nicolaysen & Westgaard 1973; Rosselle, Meirsman, De Keyser, Bovens, Geerdens, Gillard, Reynaert & Geerinckx, 1977; Rosselle, Schellens, Ghesquiere, Diniz, Geerinckx & Meirsman, 1974; Sunderland, 1968), other research indicates that terminal sprouting is reduced when partially denervated target muscles are stimulated (Brown & Holland, 1979; Brown & Ironton, 1977; Brown, Holland & Ironton, 1979; Cohan & Kater, 1986).

Electrotherapy, involving the application of electrical current at varying frequencies, intensities and phases, has been used for decades as a passive method of muscle treatment following peripheral nerve injuries. Transcutaneous galvanic or faradic stimulation is provided, each with its own waveform and frequency. Brown and Holland (1979) noted that electrostimulation appears to discourage the reformation of type I fibers that are associated with slow, fine motor control. Balliet (1989) suggested that even though electrotherapy is used frequently in treating facial paralysis, often in combination with mirror exercises, to date there is no data-based evidence suggesting that such treatment is clinically effective. In addition, Waxman (1984) reported that because electrostimulation informs the patient that his muscles are still working, electrotherapy may provide a placebo effect, which could falsely increase and maintain the patient's confidence about facial recovery. Hence, the patient may refrain from seeking other forms of treatment under the assumption that they are benefiting from the existing form of treatment. Balliet (1989) concluded by asserting that neither electrotherapy nor other forms of passive treatment are currently beneficial for neuromuscular facial retraining, and insisted that "the patient's 'active' involvement is essential to optimal recovery" (pp. 188).

Behavioral Techniques

General facial exercise techniques, such as those recommended to combat the effects of aging on muscle tone, utilize non-specific gross facial movements (Craig, 1970; Daniels & Worthingham, 1980). Balliet (1989) believes that such exercises, such as a "broad laugh," generally involve movement patterns that are either useless or contraindicated for individuals with peripheral nerve injury. Not only does he assert that such general facial exercises promote synkinesis and mass movement in patients recovering from unilateral facial paralysis, but he suggests that such exercise may encourage the development of inefficient compensatory patterns of facial motor control.

Data provided by O'Dwyer, Quinn, Guitar, Andrews and Neilson (1981), later recalculated by Balliet (1985), revealed that few facial gestures actually involve specific muscle groups. Most facial gestures utilize between two and seven primary muscle groups. Nevertheless, Balliet (1989) argued that exercises associated with isolated muscle control, such as the "unilateral snarl," which promote functional voluntary motor management, are probably more beneficial to patients with facial paralysis than gross, non-specific exercises which increase the risk of encouraging synkinesis, mass movement or a combination thereof.

Balliet (1989) introduced the notion of facial muscle retraining involving specific action exercises (SAE) which employ slow, tonic, specific (nonemotional) facial movements. Balliet stressed that practice must involve slow movement of the facial muscles. It is his opinion that this technique enables the patient to minimize activity of the non-target facial muscles, while maintaining control of the specified muscles. Balliet asserted that slow facial movements involve steady ramp-like muscle contractions that increase at a constant acceleration. The muscle contraction should be held at a maximum (that is, the maximum level of contraction possible with no associated synkinesis) for a brief period of time, 3-4 seconds, and then abruptly released. Balliet specified that the release component "helps facilitate fast and selective motoneuron inhibition and control" (pp.

191). The patient is, therefore, able to distinguish active from non-active muscle groups while developing an awareness for the sensations associated with successful movement. In addition, Balliet stressed that the patient must relax the face completely between each trial. The patient is thereby provided with information regarding his or her complete range of possible facial motor control.

The patient is always provided with visual feedback from a mirror during the production of SAE, in order to enhance restoration of voluntary control of facial symmetry. Balliet (1989) suggested that compensatory (overactive) movements of the unaffected side of the face can thus be monitored simultaneously with the practice of the SAE by the weak target muscles. In addition, visual displays of surface EMG from target muscles are sometimes utilized by clinicians and researchers during subjects' productions of SAE to provide information about underlying muscle activity. The patient is thereby provided with an additional source of sensory feedback that may enhance his or her understanding of fine motor control.

EMG feedback training allows the clinician or researcher and patient or subject to monitor when and with what amplitude specific muscles are used (Loeb & Gans, 1986). "Auditory and visual display of integrated EMG activity offer indirect feedback of motor performance in compensation for the loss of normal internal feedback" (Brown, Nahai, Wolf & Basmajian, 1978, p.189). Some clinicians feel that EMG can be especially useful as an alternate source of information about motor control for the subject when the muscle contraction is so subtle that the subject is unable to feel or see any movement (Bach-y-Rita, 1972, 1980; Balliet, 1989).

A relationship exists between the precision of muscle contraction provided by a motor unit and its innervation. Muscles that have high innervation ratios include motor units that supply a large number of muscle fibers each and have the ability to execute only gross movements with large muscle contractions. Muscles that have low innervation ratios include motor units that contain only a few muscle fibers each and are able to execute precise, fine movements involving smaller contractions (Basmajian & De Luca, 1985; McLeod, 1973; Weerdt & Harrison, 1986a; Zemlin, 1981). Facial muscles involved in speech production and facial expression tend to have low innervation ratios; fine motor control is required for speech and mimetic movements (Schwarting, Schroder, Stennert & Goebel, 1982).

Surface EMG is a noninvasive clinical and research tool which allows the mechanical contribution of multiple muscles to anatomical movements to be monitored simultaneously without significantly affecting the behavior of the subject (Loeb & Gans, 1986). In contrast to invasive monitoring techniques such as intramuscular EMG, surface EMG serves as a means of non-invasively monitoring the activity level of muscle groups during unilateral or bilateral motor behaviors.

Surface EMG Specifics and Precautionary Measures

The function of an electrode is to monitor and transduce myoelectric or EMG signals. The skin surface electrode measures the biopotentials (biological potentials) that disseminate to the surface of the skin (Basmajian, 1989).

According to Brudny, Hammerschlag, Cohen and Ransohoff (1988), EMG feedback is used to alter the patient's muscle activity, attempting to approximate the amplitude of the desired EMG response. May et al. (1989) add that selective repetition of a behavior with EMG feedback permits alteration of contralateral, homologous muscle activity which facilitates visually symmetrical gestures, appropriate motor unit recruitment, and inhibition of undesired mass movement or synkinesis.

According to Basmajian and Blumenstein (1980), surface EMG signal collection is vulnerable to measurement artifacts. The site, quality of attachment, and type and quality of electrode will affect the amount of extraneous *noise* present. The electrode-skin interface is crucial for measuring *clean* (i.e., noise free) surface EMG. To promote a *clean* recording the clinician/researcher must consider: 1) skin preparation; 2) the conductive medium; and 3) electrode attachment/placement and electrode size.

High-impedance barriers affect an electrical signal in much the same way as a large physical separation between EMG electrodes and target muscles would affect biopotentials. High-impedance barriers to EMG recordings result in lower frequency bandwidths, lower signal amplitudes, and poorer spatial selectivity (Loeb & Gans, 1986). Surface EMG already is compromised by the physical separation of electrodes and target muscles. The interface between the electrode and the skin surface can introduce yet another impedance barrier if the skin is not properly prepped. Therefore, it is necessary that surface electrodes be applied after the skin surface has been cleaned with a mild abrasive (Loeb & Gans, 1986; Jankel, 1978), to reduce the electrode-skin impedance levels to below 5 kOhms: The stratum corneum must be lightly abraded and nonconductive skin oils removed (Basmajian & Blumenstein, 1980; Basmajian & De Luca, 1985; Brown & Holland, 1979; Burbank &

Webster, 1978; Jankel, 1978; Loeb & Gans, 1986; Mulder & Boelens as cited in Weerdt & Harrison, 1986a). The addition of a conductive medium such as a hypoallergenic gel is effective in improving the electrode-skin interface, if the medium has a high electrical conductivity and is applied sparingly (Basmajian & De Luca, 1985).

Pertinent Literature Related To Application of Electromyographic Feedback and Specific Action Exercises to Facilitate Facial Muscle Control

To date, few published accounts of treatments that utilize both mirror and EMG feedback in the rehabilitation of facial paralysis/paresis have failed to vary systematically the application of either method. Hence, it is difficult to separate the beneficial training effects of each technique.

Application of EMG Feedback

Jankel (1978) reported successful use of an audio analog of facial EMG from the masseter, zygomaticus and orbicularis oculi muscles of a woman 15 years post Bell's Palsy to improve the specificity of her facial muscle movement. The subject had shown no signs of improvement in muscular control following a 6-month treatment program that included facial massage, heat and electrical stimulation which were initiated shortly after the onset of her unilateral facial paralysis. The EMG feedback study that Jankel implemented followed an A-B-A reversal design (Barlow & Hersen, 1984) with no concomitant home exercise program. Baseline data were collected over a 2-week period (daily 30-minute sessions). The treatment phase, also with daily 30-minute sessions, was 3 weeks in duration. Jankel's utilization of EMG feedback was similar to a pursuit tracking mode implemented by Booker et al. (1969). Jankel's subject was trained to track and match the muscle activity of the weak side of her face with that of the strong side. Although all three of the subject's muscle groups on the affected side showed statistically significant improvement in muscle activity, only her weak masseter and zygomatic muscle groups were able to match the activity of their stronger homologs. The results of Jankel's study suggest that EMG feedback may be a useful tool in restoring facial muscle control in subjects who are unable to benefit from other conventional forms of medical intervention or rehabilitation.

Application of EMG Feedback and Mirror Training

Booker et al. (1969) report excellent cosmetic and functional results of training using EMG feedback on the facial muscle rehabilitation of a 36-year-old woman with an XI-VII nerve transfer. The subject's facial nerve had been irreparably compromised following an automobile accident in which her temporal bone was fractured. Conventional methods of therapy such as mirror training had been unsuccessful in increasing the subject's voluntary control of the facial musculature.

Two variations of treatment were presented by Booker et al. (1969). In the first variation, visual analogs of trapezius and facial muscle EMG were displayed for the subject on an oscilloscope. A pursuit tracking mode was established so that a sine wave, externally generated, was visible on the same oscilloscope as the subject's own EMG generated from the trapezius. The subject was instructed to move the cursor representing trapezius EMG activity in synchrony with the externally generated target. Because her XI-VII transfer had surgically rerouted some peripheral fibers from the spinal root of cranial nerve XI innervating the trapezius muscle to her paralyzed facial muscles, the subject's continued practice of this procedure resulted in an increase in her voluntary facial muscle control. Once facial muscle voluntary control had been increased it was then possible to dissociate her trapezius muscle from facial movement and replace the trapezius EMG signal with an EMG signal representing only facial muscle activity. The second treatment stage included the use of a display of bilateral facial EMG activity. With this configuration the subject generated her own target, the EMG analog of facial activity on the unaffected side of her face, and tracked this "target" signal with the EMG signal generated from the weak side of her face.

The Booker et al. (1969) treatment protocol included training via an externally generated target, a self-generated target, and mirror training at home with intermittent laboratory visits to monitor symmetry of voluntary movements and resting level. Treatment was carried out over approximately 6 months with the majority of laboratory training occurring within the first 2 months. No details were given regarding the form or frequency of mirror practice between the scheduled EMG feedback enhanced treatments in the laboratory. Booker et al. (1969) reported that the subject achieved excellent results, both cosmetic and functional, suggesting that their treatment method may be applicable to similar clinical problems.

Brown et al. (1978) reported successful use of auditory and visual feedback about facial EMG activity and visual information from a mirror in the treatment of two subjects with unilateral seventh nerve damage. Both subjects reportedly had failed to recover facial muscle control on the affected side of the face using mirror feedback alone. The first subject began with a treatment paradigm that consisted of feedback about facial EMG in the form of an audible analog. Shortly thereafter visual analogs of facial EMG and mirror training were incorporated into the treatment regimen. Treatment was provided until the subject reportedly plateaued following ten weeks of therapy. Brown et al. (1978) indicate that the subject appeared to have good facial symmetry and facial muscle control, with only minimal asymmetry during speech. The second subject was initially trained in the clinic for a short period of time and then instructed to follow a home treatment program using a portable feedback instrument. This subject reportedly plateaued following 3 months of EMG feedback training, attaining facial symmetry and control when smiling. No specific information about the home training program was provided. Brown et al. (1978) concluded that their two case studies confirm that auditory and visual displays of EMG biofeedback enable individuals with facial paresis to improve facial mobility.

Daniel and Guitar (1978) found audio analogs of surface facial EMG activity to be an effective form of treatment for a 25-year-old man, five years post acoustic neuroma excision and XII-VII anastomosis. Cranial nerves III through VIII had been compressed by his acoustic neuroma. Galvanic stimulation was administered to the impaired facial muscles for several months following his anastomosis to sustain facial tone during recovery of facial animation. Electrodiagnostic evaluation of his facial muscles after 9 months of stimulation therapy revealed reinnervation of the affected side of the face. The subject had utilized a form of mirror training for 4 years without apparent success prior to initiation of Daniel and Guitar's treatment. No specifics regarding the nature of the mirror training were provided. Daniel and Guitar's therapy program spanned 6 months and was designed to help the subject regain lip control, in an attempt to increase his ability to produce symmetry in facial gestures during speech and non-speech activities.

Daniel and Guitar (1978) reported that baseline measures for surface EMG were collected with the subject receiving feedback from a mirror, permitting establishment of "functional, [symmetrical], cosmetically desirable gesture[s]" (Daniel & Guitar, 1978, p. 18). Training of four non-speech behaviors followed collection of the subject's baseline measures. Daniel and Guitar provided the subject with audio analogs of surface EMG for the affected side of his face only, though facial EMG data were recorded bilaterally. Training of the non-speech behaviors also included the utilization of mirror feedback. Among the four non-speech behaviors, the subject showed improved control for lip compression, retraction and eversion gestures, but reportedly was unsuccessful in gaining control of the muscles required for an upper lip elevation gesture. Speech training was initiated following the subject's accomplishment of a specified amplitude criterion set for the non-speech behaviors. Excellent functional and cosmetic results were reported for the speech behaviors. Daniel and Guitar report that the results were so remarkable that EMG feedback was "faded out" of the speech training condition after only four sessions.

Balliet, Shinn and Bach-y-Rita (1982) reported their success with EMG feedback followed by mirror feedback in the facial muscle retraining of four subjects. The subjects ranged from 6 months to 4 years post unilateral facial nerve injuries. The eticlogy of facial paralysis in three of the four subjects was facial nerve trauma associated with the presence and excision of an acoustic neuroma. The fourth subject exhibited facial paralysis secondary to a traumatic head injury that severed his left facial nerve. The facial retraining protocol ranged in length from 7 to 8 months and included: patient education about muscle physiology, kinesiology, and facial anatomy; relaxation training to help subjects become more aware of tonic muscle activity at rest; "face-tapping" to increase subjects' "awareness" of the weak sides of their faces; EMG feedback permitting subjects to monitor EMG signals associated with specific facial-muscle activity; specific action exercises (SAE) with feedback from a mirror, to enhance the subjects' voluntary control of target muscles; spontaneous facial exercises, to enhance automatization and generalization of symmetrical facial gestures and maintain reduced levels of synkinesis; photographic evaluations, to allow the subjects to evaluate their progress across time; and eyelid exercises, to aid the subjects' eyeclosure abilities.

In the Balliet et al. (1982) study the EMG retraining protocol included the use of a dual-channel visual analog of bilateral surface facial EMG displayed in real time on an oscilloscope. The subjects were trained to relax all facial muscles. They were then trained to produce small amplitude, slow, tonic contractions of specific muscles or muscle groups, first with the strong side of the face and then with the weak side by tracking a ramp model displayed on the oscilloscope.

When "ramp functions" were visible for the affected and unaffected sides of the face, Balliet et al. (1982) emphasized that equivalent ramp amplitudes be maintained for the bilateral EMG signal traces. Because the researchers' goal for the subjects was voluntary symmetrical facial posture, the procedure requiring equivalent "ramp functions" appears to be based on the assumption that there is a correspondence between equivalent bilateral "ramp function" amplitudes and visible facial symmetry. No empirical evidence was presented to support such a correspondence, however.

Specific action exercises (SAE) were introduced once visible movement of the muscle or muscle groups trained via EMG feedback could be seen in a mirror. The SAE were then practiced independently of EMG feedback. Subjects relied on visual feedback from a mirror, somesthesis from finger pressure on facial regions, or a combination thereof for sensory feedback about the production of symmetrical voluntary facial movements during the SAE portion of the treatment.

According to Balliet et al. (1982) all four subjects in the study acquired new voluntary motor patterns of facial movement and regained the ability to pucker, frown, smile, and close their eyes, as a result of EMG feedback, increased awareness of facial behavior, and relaxation exercises and procedures. Unfortunately, the design of this treatment protocol did not permit separation of the treatment effects of EMG feedback from those of mirror training or other components of the program.

Corral-Romero and Bustamante-Balcarcel (1982) reported results on 10 patients with unilateral facial paresis. Important improvements were noted among all ten patients. The objectives reported were to decrease asymmetry of the nasolabial fissure, eliminate mass movement, decrease asymmetry during smiling, and increase palpebral closure (eyeclosure). Unfortunately, the published account of this study failed to disclose the length of the treatment protocol, the experimental controls for extraneous variables that may have been introduced when the patient utilized mirror training in the absence of a clinician, or the methods used to ensure that the exercises performed at home were performed correctly.

Hammerschlag, Brudny, Cusumano and Cohen (1987) proposed that EMG feedback enhances rehabilitation of facial motor control in patients following XII-VII anastomosis. Feedback in the form of audio and visual analogs of facial EMG activity was provided as a treatment method for 12 of 16 subjects with unilateral facial paresis. The four subjects who did not receive EMG feedback training chose not to at their own discretion. Each of the 16 subjects was video-taped across an unspecified recovery period, while producing a specific set of facial gestures, and later each was subjectively assessed via intragroup comparisons and the House Facial Nerve Grading System (1983).[1] All 16 individuals were issued an unspecified list of facial exercises to be practiced at home in front of a mirror. Structured supervision of facial exercises was provided only for the 12 subjects participating in the EMG feedback rehabilitation program.

Although no specifics are reported by Hammerschlag et al. (1987) regarding the nature of the facial motor patterns trained in the EMG

[1] The House facial nerve grading system rates facial function by means of subjective clinical judgements of resting symmetry and tone, presence or absence of counterproductive, compensatory movements such as synkinesis, mass-action and/cr hemifacial spasm and range and symmetry of voluntary movement. The grades range from I - normal (100% function) to VI - total paralysis (0% function).

feedback program, it appears that the outcome goal was restoration of facial symmetry, thus enhancing functional voluntary and spontaneous facial movements. Spontaneity, in this context, refers to the subjects' ability to show emotional expressions without awareness or need for any tongue motions, thus indicating successful XII-VII reprogramming. Results indicated that 77% of the 12 subjects who received EMG feedback were in better House grades (i.e., II-IV), than 75% of the four subjects who did not receive EMG feedback (IV-VI). Hammerschlag et al. acknowledged that the small number of subjects in the mirror-only program (those four who did not receive EMG feedback) prevented legitimate utilization of statistical analysis procedures for their data in comparison with data for the 12 who used EMG. Nevertheless, they suggested that a trend toward better facial muscle rehabilitation appeared to exist for the patients who received EMG feedback training.

May et al. (1989) reported that 12 of 13 patients with unilateral facial paralysis as a result of Bell's palsy, whose facial rehabilitation programs included EMG feedback, achieved some improvement in facial muscle control. Each of the thirteen subjects was provided with visual feedback about facial movement from bilateral facial EMG electrodes and from a mirror, although May et al. failed to report details regarding the specific protocol followed with either method of feedback. The objectives for the patients included one or more of the following: produce visually symmetrical smiles; distinguish inappropriate eye and mouth movements; increase oral motor control; reduce hyperkinesia; and increase overall facial motor control. Overall improvement, or success of rehabilitation, was measured by the patients' physicians, who compared before and after photographs and videotapes of the patients' appearance, and by the patients themselves, who decided whether or not they had achieved predetermined goals. As May et al. suggest, the results achieved may be blemished because of the bias present in the subjective method of measurement. They go on to explain, however, that it is the patient, aided by the clinician's guidance, who determines priorities in facial reanimation. As well, they stress that "strong patient motivation and realistic expectations" (1989, pp. 220) are criteria for determining the best candidates for rehabilitation.

Evelyn (1990) implemented a pilot study of a facial muscle retraining protocol for a woman with unilateral facial weakness using a single-subject, interaction changing-criterion design. The study was designed to examine whether facial muscle EMG feedback could enhance the effectiveness of mirror training for the subject's unilateral facial weakness. The subject's paresis resulted from facial nerve trauma associated with the presence and surgical removal of an acoustic neuroma in 1982 which left her with a third degree facial nerve injury. She had participated in other facial retraining treatment programs prior to this endeavor. Her participation in this 8-week pilot study began in July 1990. The subject received 1-hour treatment sessions twice weekly, with the exception of the first and last weeks, during which three, 1-hour sessions were scheduled for baseline and follow-up data collection. The retraining protocol in that pilot study included the provision of mirror feedback about three bilateral facial gestures produced by the subject, specifically, "broad smile," "lip lift" and "lip rounding." During training, the subject was asked to perform gestures only to the extent that facial symmetry could be maintained. When the subject reached a predetermined criterion level during mirror training (i.e., when 80%, or

8 out of 10 consecutive gestures produced with visual feedback from a mirror appeared visually symmetrical, she proceeded to a mirror-plus-EMG interaction treatment phase.

The mean baseline strong-side-to-weak-side amplitude ratio for visually symmetrical gestures produced during the first mirror-only phase were used to establish initial criterion levels for EMG training. Evelyn (1990) continued collection of strong-side-to-weak-side amplitude ratios during probing in the interaction treatment phase, because a discrepancy was noted between predetermined EMG criterion lines and visual facial symmetry. There did not appear to be a consistent correspondence between apparent facial symmetry and bilaterally equivalent EMG signal amplitudes. Thus, the following question emerged: When an individual produces a visibly symmetrical facial gesture, are the amplitudes of the corresponding surface EMG signals likely to appear equivalent?

Recently, Ross, Nedzelski and McLean (1991) proposed that both EMG and mirror feedback in combination with a structured home rehabilitation program were effective treatment strategies for 25 patients with unilateral facial paresis. Treatment effectiveness was determined relative to the status of seven rural patients who did not receive treatment and therefore served as "controls." The 25 patients who received treatment were randomly assigned to mirror feedback alone or mirror-plus-EMG feedback treatment conditions. The mirror-plus-EMG condition consisted of the use of either the mirror or EMG feedback for the first half of a treatment session, and administration of the other method of feedback during the second half; the two forms of treatment were not administered concurrently.

Changes in facial motor function were assessed via the following dependent variables: facial nerve response to maximal stimulation by electroneurography; linear measurement of static facial positions/expressions based on the amount of excursion between reference landmarks; and visual assessment of patients' voluntary facial movements using a standardized videotape protocol (Ross et al., 1991). The treatment protocol involved 60-minute sessions two times per week for the first 2 weeks, once per week for the following 6 weeks and twice per month for the remaining 10 months, for a total treatment duration of 12 months. All patients who received treatment were required to follow a specific home program designed for the individual needs of each patient for a minimum of 30-60 minutes daily.

Ross et al. (1991) reported that no significant treatment effects were noted at 6 months post initiation of treatment for either treatment group compared to the controls. At the end of one year, however, statistically significant differences were found between both treatment groups and the controls for linear measures and visual assessment composite scores. No significant group effects were found in facial nerve responses to maximal stimulation by electroneurography. No significant differences were found between the subjects who received mirror training alone and those who received mirror training plus EMG feedback for any of the outcome measures. It is interesting to note that significant differences were not found between the two treatment conditions, perhaps because mirror and EMG feedback were applied in tandem, rather than concurrently across the 60-minute treatment sessions in the interaction treatment condition. Ross (personal communication,

1991) suggested that a shorter, more intense treatment protocol might lead to different results.

Rochet (1992) has compared the relative effectiveness of three facial muscle retraining methods for eight individuals with unilateral facial paresis: 1) specific facial exercise with visual feedback from a mirror; 2) specific facial exercise with visual feedback from surface facial EMG; and 3) the interaction of these two treatment methods applied together. Dependent variables included: (1) visual comparisons of facial symmetry at rest and during the production of speech and non-speech behaviors captured on video tape before and after treatment; (2) maximum EMG amplitudes recorded from perioral muscles during specific facial gestures across the treatment phases; and (3) linear distances between specific facial landmarks on both sides of a subject's face at rest measured before and after treatment. None of the outcome measures were useful in distinguishing an overall treatment effect on facial muscle control, nor was a differential effect between the treatment methods noticeable, although subjects reported improvements in perioral muscle control associated with their participation in the study. These inconsistencies may be due to the treatment duration and the sensitivity of the outcome measures utilized (Rochet, 1992).

In sum, a review of the literature reveals that audible or visible analogs of surface EMG from facial muscles during the production of specific gestures have been applied as an independent treatment paradigm, or in conjunction with mirror training to aid in the production of symmetrical facial gestures and to reduce unwanted compensatory behaviors following facial nerve regeneration. Successful results of neuromuscular retraining have been reviewed. One of these studies has explored the effectiveness of EMG feedback alone (Jankel, 1978) others explored the effectiveness of EMG feedback in combination with mirror training (Booker et al., 1969; Brown et al., 1978; Daniel & Guitar, 1978; Balliet et al., 1982; Corral-Romero & Bustamante-Balcarcel, 1982; Hammerschlag et al., 1987; May et al., 1989; Ross et al., 1991; Rochet, 1992). Although EMG feedback has been described as a valuable adjunct to traditional neuromuscular retraining, there are no empirical data that indicate EMG feedback enhances the effectiveness of mirror training when the two treatment methods are applied in a complementary relationship. As well, no evidence to date has demonstrated that a correspondence exists between visually symmetrical voluntary facial gestures and visual analogs of EMG signals with bilaterally equivalent amplitudes. The premise of this investigation is that empirical data regarding the relative effectiveness of mirror training alone, versus mirror training in conjunction with facial muscle EMG signal feedback, must be determined. The relationship between visually symmetrical facial gestures and corresponding surface EMG "ramp functions", as well as the relationship between visually symmetrical facial gestures and corresponding amplitude ratios of bilateral facial electromyograms must also be determined. Therefore, the following research questions were addressed:

1) Does the application of mirror training alone, compared to no treatment, improve the accuracy of EMG "ramp functions" corresponding to the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage?

2) Does the application of mirror training alone, compared to no treatment, improve symmetry ratings assigned to photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage?

3) Does the application of EMG feedback in conjunction with mirror training, compared to the application of mirror training alone, or no training, improve the accuracy of EMG "ramp functions" corresponding to the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage?

4) Does the application of EMG feedback in conjunction with mirror training, compared to the application of mirror training alone, or no training, improve symmetry ratings assigned to photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage?

5) What is the relationship between the accuracy of EMG "ramp functions" and symmetry ratings of corresponding photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage?

6) What is the relationship between the amplitude ratios of bilateral facial electromyograms and the symmetry ratings of corresponding photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage?

CHAPTER II. METHODOLOGY

Research Design

This research was implemented using a single-subject, experimental, interaction and multiple-baseline design across two behaviors, taking the form A-B1-BC1-B2-BC2 (Appendix A). This particular design permitted application of treatment and potential demonstration of a treatment effect in two behaviors within and across four subjects, thereby meeting the requirements suggested by McReynolds and Kearns (1983) for the minimal number of direct and systematic replications to be utilized in a multiple-baseline design.

Subjects

Potential subjects were males or females with unilateral facial paresis due to VII nerve injury associated with Bell's palsy, acoustic neuroma, inflammatory neuropathy, or trauma. The Acoustic Neuroma Association of Canada (ANAC) was the major recruitment source for the investigation.

Potential subjects were required to be at least 6-months post acute phase of a facial nerve injury, or at least 9-months post a cross-facial nerve graft or cranial nerve transfer. In 1978, Daniel and Guitar reported that electrodiagnosis 9-months post XII-VII anastomosis revealed reinnervation on the affected side of the face of a 25-year-old male. Similarly, May (1986) suggested that subjects be at least 6-months post facial nerve injury, or at least 9-months post facial nerve graft or cranial nerve transfer to allow time for spontaneous recovery, thus increasing the possibility that regenerative motor units are present to respond to facial muscle retraining. In contrast, Markley (1978) reported that reinnervation could be confirmed electromyographically, and the beginning of movement apparent 3 to 6 months post nerve graft surgery. In this investigation the more conservative inclusion criteria recommended by May (1986) were applied in an attempt to insure that some regenerative motor units would be present that might respond to treatment and to avoid the influence of spontaneous recovery on the data.

Potential subjects also were required to "pass" a surface EMG diagnostic screening procedure (see p. 36). The screening procedure was a tool used to exclude individuals who were already capable of achieving symmetrical facial gestures voluntarily, as it did not seem appropriate to take them into the study if there was no room for improvement.

Participants who met all of the inclusion criteria were three females and one male between 41 and 66 years of age. All four had acquired unilateral facial paresis as result of an acoustic neuroma which had been excised 2 to 8 years prior to their participation in this research. A summary of subject information is presented in Table 2.

Table 2. Subject Information

	Subject E.H.	Subject M.L.	Subject L.G.	Subject H.G.
Etiology	acoustic neuroma	acoustic neuroma	acoustic neuroma	acoustic neuroma
Gender	female	female	female	male
Age	52	41	43	66
General Health	fatigue, dizziness and nausea	good	good	good
Site of facial weakness	left	right	right	left
Years post onset	3	4	8	2
Reinnervation surgery?	XII-VII nerve transfer & cross-facial nerve graft	no	no	no
Surgical Reanimation?	no	no	no	no
Previous electrostimulation therapy?	no	no	yes	no
Previous facial muscle retraining	yes	yes	yes	yes

<u>Materials and Instrumentation</u>

Materials and equipment required for initial subject selection, data collection and treatment included:

(1) a preliminary information letter for potential participants (Appendix B);

(2) an "information for potential participants letter" (Appendix C);

(3) a subject consent form (Appendix D);

(4) a case history questionnaire (Appendix E);

(5) a 7" diameter mirror;

(6) three skin preparation/conductive materials:

a) MBS conductive skin prep (Multi Bio Sensors Inc., El Paso, Texas);

b) OMNI prep (OMNI Medical Division, Richmond Hills, Ontario);

c) Spectra 360 electrode conductive gel (Parker Laboratories, Inc., Orange, New Jersey);

(7) electrodes: pairs of Medi-Trace disposable silver-silver chloride pellet surface electrodes (Graphic Controls Canada Limited, Calgary, Alberta);

(8) NeuroEducator biofeedback system (Therapeutic Technologies, Inc., Daytona Beach, Florida - see Table 3 & Appendix F) supported by a laboratory dedicated microcomputer (IBM-PC XT clone);

(9) digital hand-held caliper, (Mitutoyo 505-646, Mitutoyo Corporation, Tokyo, Japan); and

(10) 35mm camera (Canon AE-1, shutter speed = 1/60s) and print film (Fuji, ASA 400).

Table 3. NeuroEducator Biofeedback System Characteristics

CHARACTERISTIC	SPECIFICATIONS
channels	4-channels (independent & isolated)
filter	band-pass filter (10 - 10,000 Hz)
sensitivity	0.2 microVolt sensitivity (within frequency response bandwidth of 10 - 1,000 Hz)
rectification	full-wave
analog integrator	simpson rectangular type 100 msec unbiased sampling windows
graphics display	0 - 800 microVolt rms range (real time color) 10 - 200 second sweep options

Training Targets

A broad smile, "smile," (target-behavior #1) and a bilateral "snarl" (target-behavior #2) constituted the probe gestures that served as the dependent variable data base. Surface EMG data associated with the performance of these gestures were collected from the following target muscle groups: the zygomatic muscle group (*m. zygomaticus majoris & minoris*), associated with lip spreading during the "smile" gesture, and the levator muscle group (*m. levator anguli oris, levator labii superioris alaeque nasi & levator labii superioris*), associated with raising the upper lip during the "snarl" probe gesture (Appendix G). Broad smile was chosen as a target gesture, not only because it is relatively easy to determine visually whether or not the gesture is symmetrical, but also because few facial muscle groups besides the zygomatic group are primarily involved in its production. Data collected by O'Dwyer, et al. (1981) and recalculated by Balliet (1985) suggest that the *m. risorius, m. buccinator* and the muscles of the zygomatic group are involved in producing a "smile." "Snarl," the second target gesture, also was chosen because of the ease of evaluating its symmetry during a bilateral production. On the basis of facial EMG data patterns reported for the production of a unilateral snarl (O'Dwyer et al., 1981), the labial levator muscle group is primarily involved in the production of this gesture.

Experimental Variables

The independent variable chosen to effect a change in performance of the target gestures was specific facial muscle training, with two levels: training performance guided by a mirror and training performance guided by a mirror and by information about surface facial EMG. Each dependent variable, performance of a "smile" and performance of a "snarl," was scored separately with respect to several performance criteria. One criterion used to analyze subjects' performance of the gestures was the assessment of facial symmetry apparent in photographs collected across the duration of the study and rated on a 4-point rating scale ranging from 0, severely asymmetrical to 3, symmetrical (see Table 5). Subject performance also was analyzed according to four specific descriptive parameters that pertained to the components of surface electromyograms associated with "smile" and "snarl" behaviors: initiation; ramp; peak amplitude hold; and gesture release (Appendix H).

Experimental Phases

There were four basic experimental phases: a pre-treatment baseline (A1), a treatment phase with mirror feedback only (B), a treatment phase with both mirror and EMG feedback (BC) and a post-treatment maintenance phase (A2). One behavior ("smile") was targeted for training first after a short baseline, while the other ("snarl") remained in baseline until its turn for treatment, according to the experimental protocol for multiple-baseline designs (Barlow & Hersen, 1984; McReynolds & Kearns, 1983; Ottenbacher, 1986). Thus, following a one week baseline, treatment was applied to performance of the "smile" gesture for 6 weeks (3 weeks in phase B1 [mirror feedback alone] and 3 weeks in phase BC1 [mirror-plus-EMG feedback], during which time the "snarl" remained in a prolonged baseline recording condition). Treatment for "smile" was then withdrawn and applied to the "snarl" gesture for the remaining 6 weeks (3 weeks in phase B2 [mirror feedback alone] and 3 weeks in phase BC2 [mirror-plus-EMG feedback], during which time the "smile" remained in a prolonged post-treatment recording condition). Therefore, the total protocol for both gestures in each subject was 13 weeks in duration (see Appendix A)

Baseline phase: A1. During the baseline phase for each gesture, photographic and surface EMG data were collected (3 probes/day, 5 days a week) as a subject performed smiles and snarls while looking in a mirror. The subject did not, however, receive any information from the investigator, acting as clinician, about the appearance of the gestures.

Treatment phases: B and BC. Probe data for both the "smile" and "snarl" target behaviors continued to be collected at the outset of every session in these phases regardless of which behavior was being trained. The remainder of the session was then devoted to treatment of one behavior or the other.

During the B phases treatment was directed at performance training of subjects' productions of "smile" (B1) and "snarl" (B2) using visual feedback from a mirror only. Each subject also was provided with verbal feedback and instruction from the clinician regarding the appearance of the target behavior as it was performed in the mirror. The subject did not, however, receive any information about bilateral facial muscle EMG activity associated with production of the gestures, even though the principal investigator stored some electromyograms associated with the training of "smile" and "snarl" gestures and therefore had access to information about the subject's facial muscle EMG activity.

The BC phases represented the interaction component of the treatment design. Mirror feedback in conjunction with EMG feedback was provided to the subject throughout each session. In a typical training session the subject performed the target gesture while looking in a mirror and immediately upon completion of the performance was able to observe the stored graphic display of electromyograms generated during the performance. Hence, this complementary application of both feedback modes was practiced in a "knowledge of results" feedback paradigm (Rubow, 1984). If the gesture did not have the target form with respect to the shape of the "ramp function" on the EMG monitor, the subject was given an opportunity to practice the gesture several times with on-line feedback from the EMG monitor to refine the performance of the displayed "ramp function." If the gesture did not have the target form with respect to its visible symmetry in the mirror, the subject was given an opportunity to practice the gesture several times in the mirror to refine the visible symmetry of the performance.

The original intent of the investigator was to establish criterion levels for EMG training during A- and B-phase probes and B-phase treatment sessions that could be increased systematically across time (i.e., 10% increases when an 80% success rate was achieved for present criterion levels) to introduce opportunity for increased excursion levels of the target muscle group on the weak side of a patient's face during BC training. Day-to-day instrumental variation made it impossible to utilize this procedure, however. Therefore, criterion levels for EMG training were established as follows: A mean ratio of EMG amplitudes generated by target muscles on the "strong" and "weak" sides of a subject's face were calculated from all microVolt ratios that corresponded to visually symmetrical facial gestures produced during A- and B-phase probes and B-phase treatment sessions. For example, if a "snarl" probe gesture appeared visually symmetrical when the amplitudes for the "strong" and "weak" sides of the face were 10 and 18 microVolts respectively, then the strong-side-to-weak-side amplitude ratio would be 1:1.8. These criterion levels were used to set the levels of the initial training lines for the "ramp function" plateau for which subjects strived on the EMG monitor during the BC phases. Unfortunately, it was necessary to readjust the level of the training line on a daily basis because of a 10 - 20% variance in amplitude levels associated with the instrumental variation of the EMG biofeedback system. This discrepancy made it impossible to utilize consistent training-line amplitude levels day-to-day or to increase the training target systematically when a performance criterion was achieved. As a result, amplitude adjustments to the training line were calculated from probe data amplitude ratios collected at the outset of each treatment session.

Maintenance phase: A2. A prolonged post-treatment maintenance phase existed for the "smile" gesture only (just as a prolonged baseline phase was present for the "snarl" gesture alone). Probe data for the smiles and snarls continued to be collected at the outset of every session in this phase. The remainder of the session was devoted to treatment of the "snarl" gesture.

Procedures

Subject Selection

Individuals who responded to the preliminary information letter for potential participants (Appendix B) were asked to attend the research site at the University of Alberta so that eligibility could be determined via a diagnostic screening procedure. Subjects who were eligible to participate in the study on the basis of this evaluation were re-apprised of the purpose and procedures involved in the study (Appendix C), asked to complete a case history questionnaire (Appendix E) and their written consent was obtained (Appendix D). Subject characteristics are exhibited in Table 2 (p. 29).

Surface EMG and Visible Symmetry Diagnostic Screening Procedure. During the screening procedure EMG signals from surface electrodes over muscles on both sides of a subject's face were observed while certain facial gestures were performed across five repetitions. Information obtained from the screening procedure assisted the investigator in identifying subjects who exhibited a naturally large dissimilarity in bilateral EMG amplitudes for homologous facial muscle groups, and visible facial asymmetry during the production of specific facial gestures using those muscle groups. A large, reliable difference in EMG amplitudes between homologous facial muscles bilaterally suggested some potential for improvement in the weaker side within the limits of this study.

Experimental Schedule

Probe Data Collection and Schedule. A critical component of single-subject designs is continuous probe data collection across time, yielding a large data base that can be examined for information about changes in the dependent variable(s) (Barlow & Hersen, 1984; McReynolds & Kearns, 1983; Ottenbacher, 1986). The present investigation satisfied this requirement as follows: Surface EMG amplitude-by-time records for subjects' performances of probe gestures and 35mm photographs of the best moments of those performances, based on subjects' judgements, were obtained during pre-treatment baseline sessions and at the beginning of each treatment and maintenance session for the duration of the investigation.

Treatment Schedule. Subjects attended the research clinic for one hour sessions, five times weekly across 13 weeks. Admittedly, the subjects' attendance schedules were intense. Published research indicates, however, that in order to observe improvements when treating unilateral facial paresis, a substantial time commitment for treatment is required, utilizing an intense direct or indirect exercise protocol (Balliet et al., 1982; Booker et al., 1969; Brown et al., 1978; Daniel & Guitar, 1978; Jankel, 1978; Ross et al., 1991). Indirect protocols must rely on homework to maintain treatment intensity when subjects are not available for direct interaction with a clinician. Homework was not included in this experimental treatment program, however, because the intensity of treatment was such that subjects attended the research clinic 5 days weekly. Furthermore, the reliability of a homework program is unknown, and subjects tend to differ in their compliance with a homework exercise regimen.

Electrode Placement

At the outset of each session, prior to probe data collection, each subject's facial skin was prepped in a standard manner that was reliable from day-to-day. Electrodes then were placed on the skin, and bilateral surface EMG records and photographs were made of subjects' performances of specific facial gestures.

Day-to-day reliability of surface EMG sampling also is a function of impedance of the electrode-skin interface. Skin surface impedance was reduced via a standardized skin preparation procedure. Surface EMG sampling did not commence until baseline noise in the surface EMG signal was less than or equal to 5 microVolts. This low baseline noise criterion was used as an indirect means of inferring that the integrity of the skin-electrode interface was satisfactory enough to proceed with EMG data collection/training.

Reliability of electrode placement across the duration of the experimental period was enhanced by documenting initial electrode placements with 8" x 10" photographs, video-taped records and linear measurements using a digital hand-held caliper to which the investigator referred for all subsequent placements.

Probe Data Acquisition

During the collection of probe data, subjects were seated in a chair designed to maximize stable and consistent head positioning across the 13-week period. Additionally, the backdrop was consistent across time in depth and color for photographic purposes, and a constant camera-to-subject distance was maintained throughout the investigation.

For each probe gesture the subject was asked to look in the mirror and produce a "smile" or "snarl" gesture to the greatest excursion that could be done symmetrically. A demonstration by the clinician was given and three practice trials were allowed prior to collection of surface EMG and photographic data to ensure the subject produced gestures as reliably as possible. The subject was given access to a remote shutter trigger and asked to take his/her own picture once he/she judged the target behavior to be symmetrical in the mirror. Bilateral surface EMG data from the zygomatic and levator muscle groups were collected during the performance of gestures that were photographed. Order of probe data collection was counterbalanced daily. That is, if the subject produced three "smile" gestures prior to three "snarl" gestures on a given day, on the following day data for the "snarl" gestures were collected before those for the "smile."

Treatment Application

During both the "mirror-only" and "mirror-plus-EMG" treatment conditions a schematic model (Appendix I) of desired performance characteristics was used to help the subject conceptualize the production of "smile" and "snarl." The behavioral components of this model included instructing the subject to: (1) initiate the gesture with the weak side of the face and then allow the strong side to become involved in the production of the gesture; (2) reach the maximum symmetrical excursion of the gesture slowly; (3) stabilize the maximum symmetrical extent of the target gesture; (4) abruptly release all muscle groups involved in the production of the target gesture; and (5) completely relax all facial muscle groups between each trial gesture. Thus, the subject was coached to produce each trial with a slow onset that was initiated on the weak side, a brief hold at the gestures best symmetrical excursion, and an abrupt, complete release. Every trial performance was followed by a brief rest period (Daniel & Guitar, 1978; Balliet, 1989). In addition, subjects were instructed to immediately terminate production of the target gesture if "mass action" or "co-contraction" was observed by either the subject or the clinician.

These behavioral components were included in the B and BC training protocols because of indications provided by Balliet (1989) that these actions facilitate facial motor control in patients with unilateral paresis. In particular, with respect to the behavioral component associated with the onset of a training gesture, Balliet suggests that if a subject begins with the weak side of the face, the clinician can presume that efforts are being made by the subject to inhibit the tendency for increased activity that often characterizes behavior of the unaffected side of the face, and to encourage an increase in the amount of activity on the affected side. Thus, it is presumed that the subjects are working towards decreasing facial activity imbalance (Appendix J). Balliet (1989) suggests that this procedure "promotes either equal innervation of both the involved and uninvolved sides or innervation of the involved side followed by innervation of the uninvolved side" (pp. 192) of the face. Furthermore, according to Balliet, cessation of facial activity when mass action or unwanted co-contraction is observed facilitates improved facial motor control. Therefore, if at any time during the present treatment the clinician observed extraneous movements that were construed to be associated with mass action or co-contraction, the subject was asked to stop and produce the gesture again. This procedure was utilized to help reduce the frequency of asymmetrically produced facial gestures and increase the frequency of facial gestures that were perceived as visually symmetrical.

Because probes were obtained at the outset of every treatment session, subjects had electrodes placed on the skin over the target muscles during both B and BC phases. Thus, even though EMG feedback was made available to each subject during only the BC phases, the electrodes remained in place for the duration of each session during all treatment phases. This process controlled for the mechanical load of the electrodes during all phases of the experiment and thus helped ensure that the presence of the electrodes was not a confounding variable between B and BC training conditions.

Electromyographic Data Analysis

Qualitative. Hard copies of the surface electromyograms associated with performance of probe target gestures were printed at the end of each experimental session for each subject (3 probes x 2 gestures = 6 electromyograms/subject/session). A total of 1560 electromyograms, the entire probe data sample, were used for data analysis (3 probes x 2 gestures x 4 subjects x 5 days/week x 13 weeks = 1560). A table of random numbers was used to code all electromyograms to determine the sequence in which they were analyzed and to prevent an experimental order effect on the rater's analyses. With the exception of the assessment of electromyographic data reliability, the principal investigator was the only individual involved in analysis of the electromyographic data. Descriptive analyses of all of the electromyograms corresponding to probe data collected for each of the four subjects were performed after each subject's participation in the study terminated. Hard copies of electromyographic data for one subject were analyzed by the investigator in their entirety before the analysis of electromyographic data for another subject commenced.

Descriptive analyses were based on four "ramp function" parameters (initiation, ramp, hold & release) (see Table 4). Appendix K lists the criteria established and used by the principal investigator as guidelines for what defined a satisfactory parameter. These criteria were based on 16 example electromyograms produced specifically for training purposes. The subjects' electromyograms then were analyzed utilizing the reference electromyograms and the predetermined criteria.

Table 4. Descriptive "Ramp Function" Parameters for EMG Data

PARAMETER	DESCRIPTION
Initiation	The weak (affected) side of the face initiates the gesture
Ramp	A gradual slope of the "ramp function" is apparent.
Hold	Following the "ramp" an amplitude plateau is stabilized for 2-3 seconds.
Release	The plateau terminates with an abrupt, complete release bilaterally.

Quantitative. Visual inspection of the graphs of the "smile" and "snarl" electromyographic data (Figures 1 A - D, pp. 54-57) for all subjects, combined with the use of descriptive statistics, were utilized to evaluate the experimental treatment effect of the independent variable, facial muscle retraining. Visual inspection is concerned with noting changes in the dependent variable(s) that have occurred across phases of an experimental investigation. Barlow and Hersen (1984) and Ottenbacher (1986) note that visual analysis may yield limited information if the baseline trend is unstable, if high intrasubject variability is present in the data series or if the data exhibit serial dependency. Although the data for this investigation displayed all three of the above factors, supplemental statistical procedures could not be employed effectively. Lag-3 autocorrelation coefficients (Ottenbacher, 1986) were computed for each pertinent data series and

Bartlett's test was calculated for each lag. This procedure confirmed that the autocorrelation coefficients were statistically significant. Moving average transformations were not successful in either removing the serial dependency or reducing the autocorrelation coefficients to non-significant levels. As a result, two-standard-deviation bandwidths could not be calculated; this procedure requires that the data series do not exhibit significant serial dependency. Utilization of a C-statistic was the next method of choice for data analysis, because it can be applied to data series that exhibit serial dependency. Unfortunately, the baseline data series for several subjects displayed statistically significant trends. Ottenbacher suggests that it is not appropriate to add baseline and intervention scores together, the second step in calculating a C-statistic, if the baseline data evidence a statistically significant trend. Alternative procedures used in calculating a C-statistic may affect the interpretation of the results and therefore have limited value. Therefore, only visual inspection of all graphs comprising the "smile" and "snarl" data and a comparison of mean "ramp function" accuracy values across the experimental phases, were used to answer experimental questions one and three.

Calculation of Bilateral EMG Amplitude Ratios. Amplitude ratios were calculated for all bilateral surface facial electromyograms corresponding to the performance of "smile" and "snarl" probe gestures. Three steps were involved in calculating these ratios: (1) the electromyogram was examined to determine the duration of the "hold" period in seconds, from moment of initiation of the hold, to moment of its release; (2) the corresponding numerical printout of EMG amplitudes in microVolts at 500ms intervals, was used to calculate the mean amplitude bilaterally for the "hold" period; and (3) the mean EMG amplitude for the subject's weak facial muscle group during the hold period was divided by the corresponding mean amplitude for the strong muscles in order to compute an amplitude ratio for a given electromyogram.

Photographic Data Analysis

Qualitative. Photographs associated with performance of probe target gestures were printed at the end of each experimental session for each subject (3 probes x 2 gestures = 6 photographs/subject/session). A total of 1560 photographs, the entire probe data sample, were used for data analysis (3 probes x 2 gestures x 4 subjects x 5 days/week x 13 weeks = 1560). A table of random numbers was used to code all photographs to determine the sequence in which they were rated and to prevent an experimental order effect on the rater's analyses. With the exception of the assessment of photographic data reliability, the principal investigator was the only individual involved in rating the photographs with respect to apparent visible symmetry. Descriptive analyses of all of the photographs corresponding to probe data collected for each of the four subjects were performed after each subject's participation in the study terminated. Photographs for one subject were rated by the investigator in their entirety before symmetry rating of photographs for another subject commenced.

Table 5. Symmetry Rating Scale and Corresponding Subjective Judgements

RATING	SUBJECTIVE JUDGEMENT
3	symmetrical
2	mildly asymmetrical
1	moderately asymmetrical
0	severely asymmetrical

Descriptive analyses of the photographs were accomplished by utilizing the 4-point rating scale shown in Table 5. Appendix L (1 - 4) lists the criteria established and used by the principal investigator as guidelines for judging facial symmetry in the photographic data. These criteria were based on 16 example photographs of each subject. The subjects' photographs then were analyzed utilizing the reference photographs and the predetermined criteria.

Quantitative. Visual inspection of the graphs of the "smile" and "snarl" symmetry rating data (Figures 2 A - D, pp. 62-65) and a comparison of mean symmetry ratings across the experimental phases were utilized to evaluate the experimental treatment effect of the independent variable, facial muscle retraining, and answer experimental questions two and four.

Reliability

Electromyographic data. A total of 10.25% (160 electromyograms) of the entire probe data sample was used to calculate interjudge reliability across all subjects. Specifically, percentage agreement scores were calculated for the electromyograms corresponding to the final two of the three probe gestures collected during the last two sessions of each experimental phase for both target gestures (2 probes x 2 sessions x 5 phases [A1, B1, BC1, B2, BC2] x 2 gestures x 4 subjects = 160). Thus, data for reliability were called from each experimental phase. The electromyograms had been coded prior to initial electromyographic data analysis and these same codes were used to determine the sequence in which the data were rated to assess interjudge reliability. Two judges participated in assessing the accuracy of the electromyograms. Judge #1 was the primary investigator, and judge #2 was a speech-language pathologist external to the investigation. The external judge was apprised of the purpose and procedures involved in the study, as well as the training program she would receive and the time commitment required. Additionally, the volunteer's written consent was obtained (Appendix M). Interjudge reliability on the descriptive analyses of the electromyograms was determined by calculating point-to-point percentage agreement scores for the two judges who analyzed selected electromyograms corresponding to "smile" and "snarl" gestures produced by all subjects. Judgements were considered in agreement when the judges' analyses for the same electromyogram were consistent with one another with respect to all parameters of the "ramp function" (initiation, ramp, hold & release). Interjudge reliability is tabulated in Table 7 (p. 70).

The principal investigator used a table of random numbers to determine which electromyograms would be reassessed by the judges to establish intrajudge reliability. Electromyograms were reassessed by both raters approximately 1/2 hour after the completion of the initial judging task. Because the interjudge reliability task was time-consuming, intrajudge reliability was determined on only 10% (16 electromyograms) of the probe sample used to calculate interjudge reliability. Intrajudge reliability for repeated ratings is tabulated in Table 8 (p. 71) for the "smile" gesture and Table 9 (p. 71) for the "snarl" gesture.

Judge #2 underwent a 2-hour training process to prepare for the descriptive analyses of electromyograms after the primary investigator established the criteria for the four target electromyogram parameters. Materials used to train judge #2 included the 16 reference electromyograms produced specifically for training purposes. The initial 1 1/2 hours of the training session were broken down into four, 22-minute segments during which the principal investigator described to the external judge each of the four parameters to be studied (initiation, ramp, hold & release); together the two individuals assessed the descriptive features apparent in the electromyograms. The remaining 1/2 hour involved independent analyses of electromyograms by the external judge and the investigator and subsequent comparison of judgements. This training terminated when approximately 95% reliability was established between the external judge and the investigator for assessment of selected electromyograms. Following the training session the external judge was given a 1/2-hour break and then began to judge the experimental EMG data. The external judge required approximately 5-hours, excluding three 20-minute breaks each between the completion of one subject's data and the commencement of another subject's data, to complete the initial analysis of 10.25% (160 electromyograms) of the entire EMG data sample, or 40 electromyograms of each subject's data (20 of each gesture [2 probes x 2 sessions x 5 phases = 20]).

Photographic data. A total of 10.25% (160 photographs) of the entire probe data sample was used to calculate interjudge reliability across all subjects. Specifically, percentage agreement scores were calculated for the photographs corresponding to the final two of the three probe gestures collected during the last two sessions of each experimental phase for both target gestures (2 probes x 2 sessions x 5 phases [A1, B1, BC1, B2, BC2] x 2 gestures x 4 subjects = 160). Thus, data for reliability were called from each experimental phase. The photographs had been coded prior to initial photographic data analysis and these same codes were used to determine the sequence in which the photographs were rated to assess interjudge reliability. Three judges participated in assessing the accuracy of the photograph symmetry ratings. Judge #1 was the primary investigator, and judges #2 and #3 were speech-language pathologists external to the investigation. The external judges were apprised of the purpose and procedures involved in the study, as well as the training program they would receive and the time commitment required. Additionally, the volunteers' written consent was obtained (Appendix N). Interjudge reliability on the descriptive analyses of the photographs was determined by calculating point-to-point percentage agreement scores for the three judges who analyzed selected photographs corresponding to "smile" and "snarl" gestures produced by all subjects. Judgements were considered in agreement when the judges' analyses for the same photograph were consistent with one another using the symmetry ratings in Table 5 (p. 45). Interjudge reliability is tabulated in Table 10 (p. 72).

The principal investigator used a table of random numbers to determine which photographic data would be reassessed by the judges to establish intrajudge reliability. Photographs were reassessed by all raters approximately 1/2 hour after the completion of the initial judging task. Because the interjudge reliability task was time-consuming, intrajudge reliability was determined on only 10% (16 photographs) of the probe sample used to calculate interjudge reliability. Intrajudge reliability for repeated ratings is tabulated in Table 11 (p. 73) for the "smile" gesture and Table 12 (p. 73) for the "snarl" gesture.

Each of the external judges underwent a 3-hour training program to prepare for the symmetry rating task after the primary investigator established the criteria for the symmetry rating scale (Appendix L [1-4], pp. 134-140). Materials used to train the judges included reference photographs. These photographs were selected from the experimental data pool but were not data that were included in the inter- or intra-judge reliability procedure. The reference photographic data had been used by the investigator initially in establishing the criteria for the symmetry rating scale. The initial two hours of the training session were broken down into four, 1/2-hour segments during which the principal investigator described to the external judge each of the four parameters to be studied (visible symmetry, mild asymmetry, moderate asymmetry and severe asymmetry); together the three individuals assessed the varying degrees of facial symmetry apparent in selected 5" x 7" color photographs. The remaining one hour involved independent analyses of photographs by the external judges and the investigator and subsequent comparison of judgements. This training terminated when approximately 95% reliability was established between the external judges and the investigator for assessment of selected photographs. Following the training session the external judges were given a 1/2-hour break and then began to judge the experimental photographs. Each external judge required approximately 5-hours, excluding three 20-minute breaks each between the completion of one subject's data and the commencement of another subject's data, to complete the initial analysis of 10.25% of the entire photographic data sample.

CHAPTER III. RESULTS

Descriptive Statistics

Analysis of Electromyographic Data. Descriptive data for the analysis of "ramp function" accuracy consisted of the percent accuracy scores associated with each subject's production of "smile" and "snarl" gestures during the baseline phase of the experiment and at the outset of each treatment session. Accuracy scores were obtained from the principal investigator's visual inspection of all surface facial electromyograms (three of each facial behavior/day). "Ramp function" accuracy scores are composites based on the presence or absence of the four "ramp function" parameters: initiation; ramp; hold; and release. Figures 1 (A - D) show "smile" and "snarl" accuracy scores plotted across time for each of the four subjects; mean "ramp function" accuracy scores for each experimental phase are indicated on the graphs. Presentation of the results associated with "ramp function" accuracy is with respect to mean score differences between baseline and both treatment phases and between the two different treatment condition phases.

Figure 1-A illustrates data for subject E.H. for the "smile" gesture. The data exhibited an increased mean "ramp function" accuracy score during the application of mirror training (phase B1; mean accuracy = 40%) compared to her mean accuracy score during baseline (phase A; mean accuracy = 30%). Her mean accuracy score continued to increase during the application of both treatments (phase BC1; mean accuracy = 60%) and decreased during the maintenance period (mean accuracy = 50%). Her data for the "snarl" training gesture, in the lower portion of

Figure 1-A, exhibited a response pattern similar to that for the "smile." Data for the prolonged baseline period were more or less stable until near the end of this phase (mean accuracy = 30%). Her mean accuracy score increased with the application of mirror feedback (phase B2; mean accuracy = 40%), and continued to increase when feedback from the mirror and levator group EMG were applied together in training (phase BC2; mean accuracy = 50%). Thus, the overall treatment response exhibited in her "smile" training data is replicated in her accuracy data during "snarl" training.

Figure 1-B illustrates the "ramp function" accuracy data for subject M.L.. Her mean "smile" accuracy scores indicate that she produced increasingly more accurate "ramp functions" during the application of mirror training (phase B1; mean accuracy = 70%) than during baseline (mean accuracy = 50%). Her mean accuracy continued to increase during the application of both treatments (phase BC1; mean accuracy = 80%). Data for the prolonged baseline period for "snarl," in the lower portion of the figure, exhibit an increase in "ramp function" accuracy about half-way through this phase (mean accuracy = 60%). Her mean accuracy for the "snarl" training gesture increased only slightly once mirror training was implemented (phase B2; mean accuracy = 70%). No further increases were exhibited when feedback from the mirror and levator group EMG were applied together (phase BC2; mean accuracy = 70%). In summary, mean "ramp function" accuracy data for subject M.L. exhibit an overall treatment difference compared to baseline for her "smile" gesture. "Ramp function" accuracy changes between her mean baseline data for "snarl" and her mean B2 and BC2 accuracy scores are

minimal. A between-treatment difference is apparent only between B1 and BC1 accuracy scores for her "smile" data.

Figure 1-C illustrates the response of subject L.G. to the two treatment methods. This subject exhibited a higher mean accuracy score for the "smile" target gesture during baseline (mean accuracy = 80%) than during mirror training (phase B1; mean accuracy = 70%). Her mean accuracy score increased above the level of both the baseline and the mirror training levels, however, during the application of the two treatments (phase BC1; mean accuracy = 90%). Her mean percent accuracy score stabilized during the maintenance period (mean accuracy = 90%), when treatment of the zygomatics was withdrawn and applied to the levator muscle group for the "snarl" gesture. Data for the prolonged baseline phase for the "snarl" gesture, in the lower portion of the figure, exhibit an increase in mean "ramp function" accuracy across the 7-week period (mean accuracy = 80%). Her mean "ramp function" accuracy for the "snarl" training gesture decreased during mirror training (phase B2; mean accuracy = 70%) compared to her prolonged baseline (mean accuracy = 80%) and then stabilized when the two treatments were applied together (phase BC2; mean accuracy = 70%). In summary, the mean "ramp function" accuracy data for subject L.G. exhibit an overall treatment difference compared to baseline data for her "smile" gesture but not for her "snarl" gesture. Similarly, a between-treatment difference appears to exist for the data associated with her "smile" gesture (B1 & BC1) but not her "snarl" gesture.

Figure 1-D illustrates the "ramp function" accuracy data for subject H.G.. His mean accuracy for productions of the "smile" target gesture increased with the application of mirror feedback (phase B1;

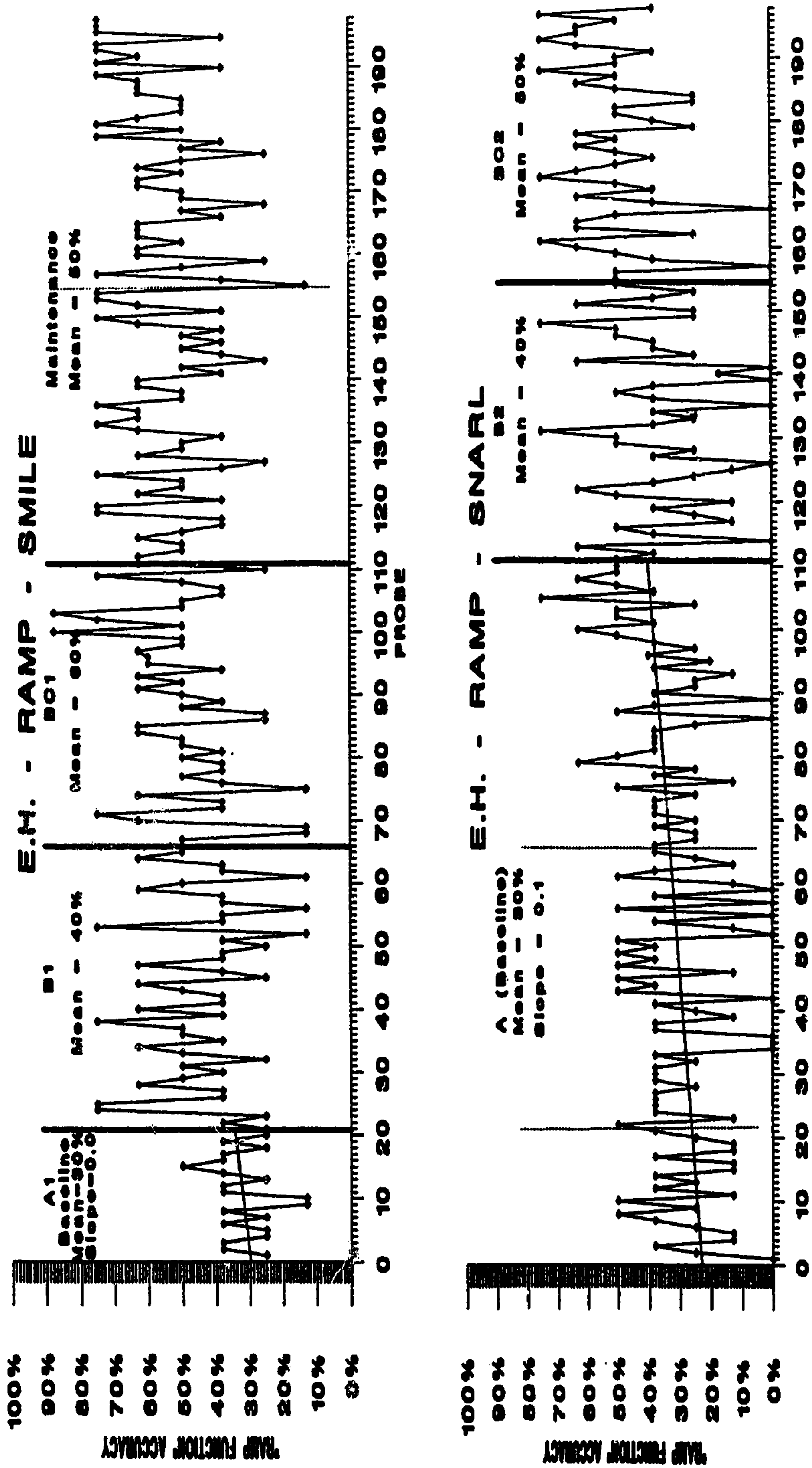

Figure 1-A. "Ramp function" percent accuracy scores of subject E.H. for each electromyogram across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

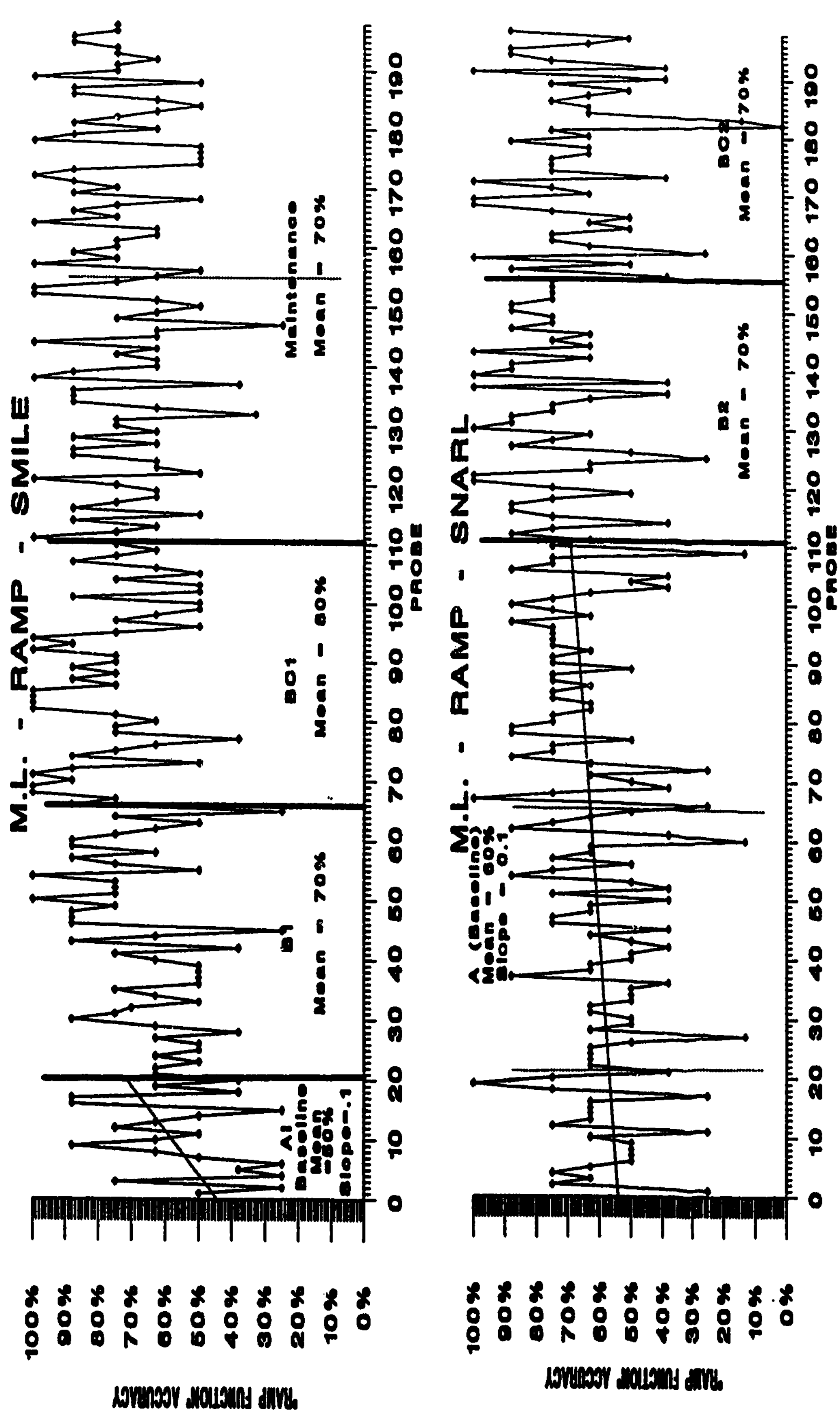

Figure 1-B. "Ramp function" percent accuracy scores of subject M.L. for each electromyogram across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

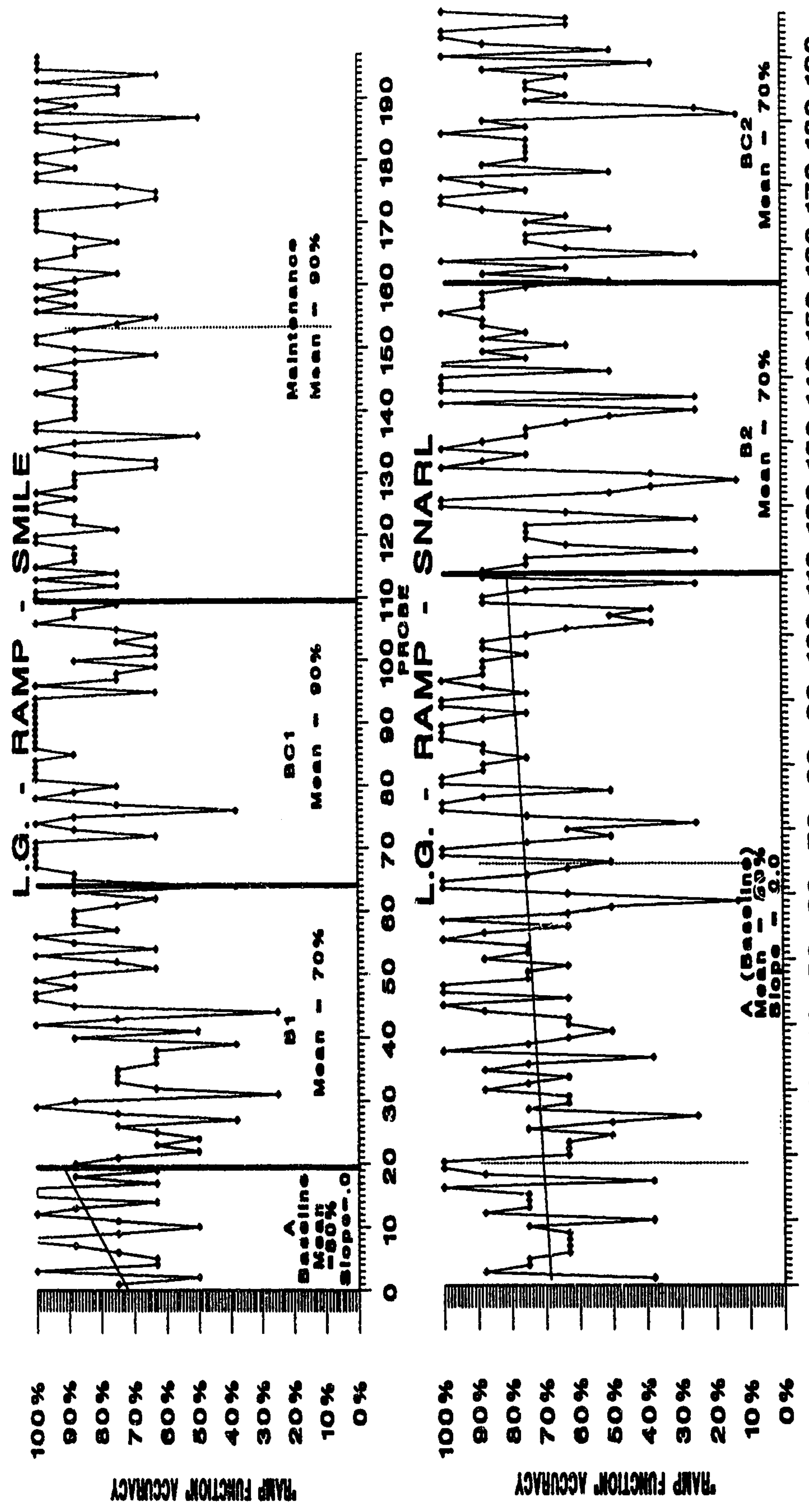

Figure 1-C. "Ramp function" percent accuracy scores of subject L.G. for each electromyogram across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

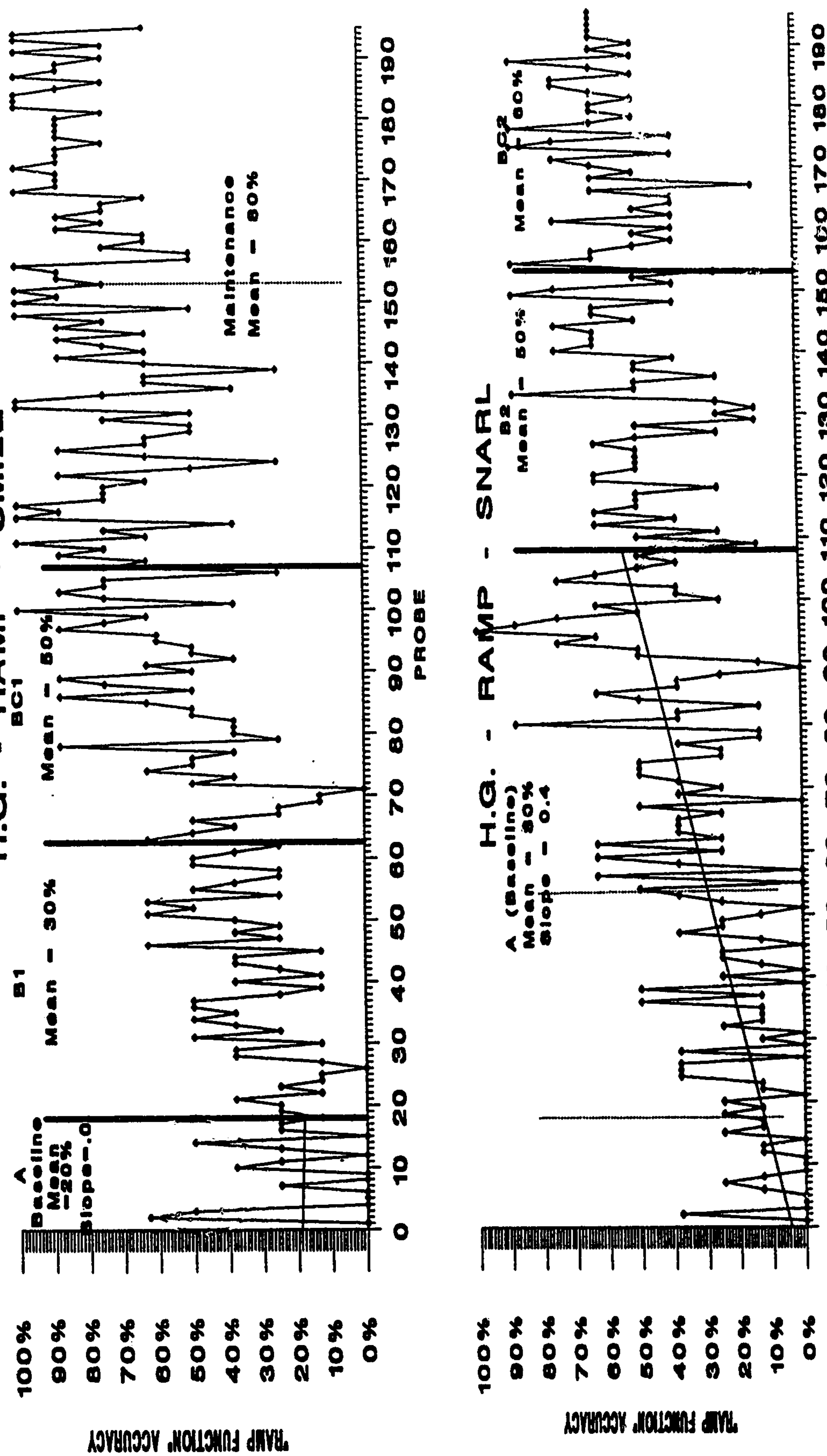

Figure 1-D. "Ramp function" percent accuracy scores of subject H.G. for each electromyogram across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

mean accuracy = 30%) compared to his mean accuracy score during baseline (phase A; mean accuracy = 20%). His mean percent accuracy score continued to increase during the application of both treatments (phase BC1; mean accuracy = 50%) and during the maintenance period (mean accuracy = 80%), when treatment of the zygomatics was withdrawn and applied to the levator muscle group for the "snarl" gesture. His data for the "snarl" gesture, in the lower portion of the figure, exhibit a response pattern similar to that for the "smile." Data for the prolonged baseline period increased across the duration of the A phase (mean accuracy = 30%). His mean "snarl" accuracy score increased with the application of mirror feedback (phase B2; mean accuracy = 50%) and continued to increase during the application of both treatments (phase BC2; mean accuracy = 60%). Thus, mean "ramp function" accuracy data for subject H.G. exhibit an overall increase during treatment compared to baseline value for both his "smile" and "snarl" gestures. Additionally, a between-treatment difference is apparent for the data associated with his "smile" and "snarl" gestures.

In summary, the "ramp function" accuracy data derived from electromyograms of subjects' "smile" and "snarl" gestures across the experimental period were characterized by the following features: (1) all subjects showed some response to the application of treatment for one or both gestures; (2) between-treatment differences were exhibited in the "smile" mean "ramp function" accuracy data across all subjects; and (3) between-treatment differences were exhibited in the "snarl" data obtained from two of the four subjects. Whether the B1 versus BC1 and B2 versus BC2 differences in mean "ramp function" accuracy scores constitute a between-treatments effect is equivocal, however. This issue will be addressed in the Discussion chapter.

Analysis of Photographic Data. Descriptive data for the analysis of facial symmetry consisted of symmetry ratings associated with each subject's production of "smile" and "snarl" gestures across baseline and treatment conditions. Symmetry ratings were obtained from the principal investigator's visual inspection of 5" x 7" color photographs (three of each facial behavior/day). Symmetry ratings were based on a 4-point rating scale ranging from 0 to 3 (severely asymmetrical to symmetrical). Figures 2 (A - D) are composed of plots of the "smile" and "snarl" symmetry ratings obtained from the serial photographs for each of the four subjects; mean symmetry ratings for each phase are indicated on the graphs. Presentation of the results associated with symmetry ratings is with respect to mean score differences between baseline and both treatment phases and between the two different treatment condition phases.

Figure 2-A illustrates the symmetry ratings for subject E.H. for both facial gestures. As shown in the "smile" symmetry data graphed at the top of the figure, she exhibited consistently low symmetry ratings throughout baseline (phase A; mean rating = 0). Her mean symmetry rating increased during the application of mirror training for this gesture (phase B1; mean rating = 1.0) and continued to increase during the application of both treatments (phase BC1; mean rating = 1.8). An increase in her mean symmetry rating for the "smile" gesture was evident during the maintenance period (mean rating = 2.2), when treatment of the zygomatics was withdrawn and applied to the levator muscle group for the

"snarl" gesture. Her data for this gesture, in the lower portion of Figure 2-A, exhibit a response pattern similar to that for the "smile." Data for the prolonged baseline period were more or less stable (mean rating = 0.1). Her mean symmetry rating increased with the application of mirror feedback (phase B2; mean rating = 1.6), and continued to increase when feedback from the mirror and levator group EMG were applied together in training (phase BC2; mean rating = 2.2). Thus, an overall treatment difference exhibited in her "smile" training data is replicated in her response to "snarl" training. Visual inspection of the symmetry rating data does not reveal whether the B1 versus BC1 and B2 versus BC2 differences in this subject's mean symmetry ratings constitute a between-treatments effect.

Figure 2-B illustrates the symmetry ratings for subject M.L. for both facial gestures. As shown by the "smile" symmetry data graphed at the top of the figure, she exhibited essentially no difference in her mean symmetry ratings between baseline (mean rating = 1.9) and the mirror feedback phase of training (phase B1; mean rating = 2.0). Her mean symmetry rating increased during the application of both mirror and EMG feedback (phase BC1; mean rating = 2.6), however, and reached a ceiling for that gesture during the maintenance period (mean rating = 3.0). Her data for the "snarl" gesture, in the lower portion of Figure 2-B, exhibit a response pattern comparable in form and degree to that for the "smile," but temporally different. Her symmetry rating during the prolonged baseline period increased across the duration of the A phase (mean rating = 1.5). Her mean "snarl" symmetry rating increased with the application of mirror feedback (phase B2; mean rating = 2.1), however, and reached a ceiling for the gesture when feedback from the

mirror and levator group EMG were applied together (phase BC2; mean rating = 3.0). Thus, she exhibited an overall treatment difference compared to baseline data for both facial muscle gestures. Apparent between-treatment differences in this subject's data are confounded by generalization and ceiling effects, however.

Figure 2-C illustrates the symmetry ratings for subject L.G. for both facial gestures. As shown by the "smile" symmetry data graphed at the top of the figure, she displayed consistently low symmetry ratings throughout baseline (phase A; mean rating = 0). Her mean symmetry rating increased during the application of mirror training for this gesture (phase B1; mean rating = 1.2), and increased slightly during the application of both treatments (phase BC1; mean rating = 1.4). Her mean symmetry rating for the "smile" gesture stabilized during the maintenance period (mean rating = 1.5), when treatment of the zygomatics was withdrawn and applied to the levator muscle group for the "snarl" gesture. Her data for the "snarl" gesture, in the lower portion of Figure 2-C, exhibit a response pattern similar to that for the "smile." Data for the prolonged baseline period were more or less stable (mean rating = 0.3) with the exception of one outlier early in the A phase. Her mean symmetry rating increased with the application of mirror feedback (phase B2; mean rating = 2.3). Her mean symmetry rating for the "snarl" gesture stabilized when feedback from the mirror and levator group EMG were applied together in training (phase BC2; mean rating = 2.2). Thus, the overall increase in symmetry ratings during treatment exhibited in her "smile" data is replicated in records for "snarl." A between-treatment difference is not pronounced in the data records for either the "smile" or the "snarl" gesture.

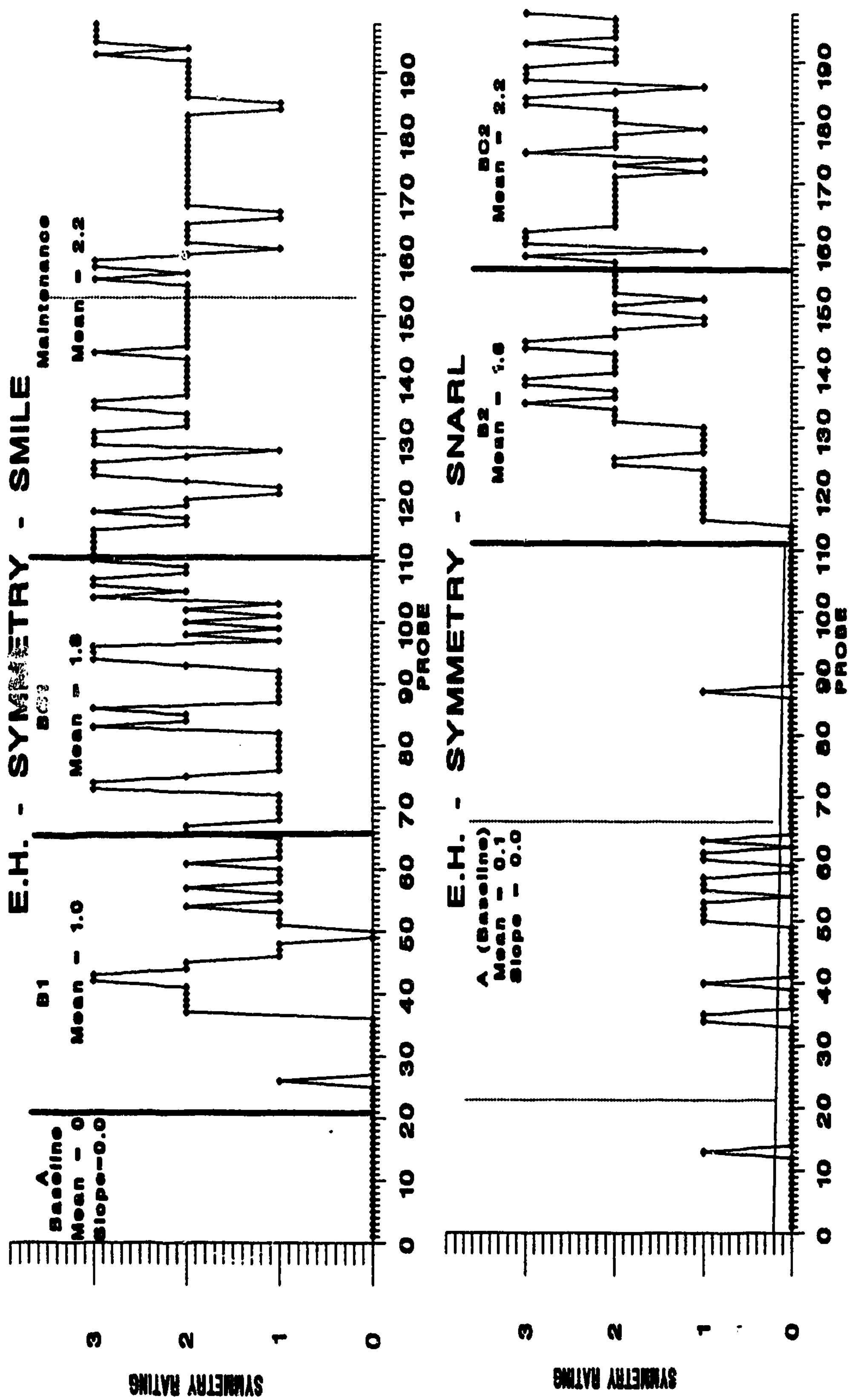

Figure 2-A. Symmetry ratings of subject E.H. for each photograph across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

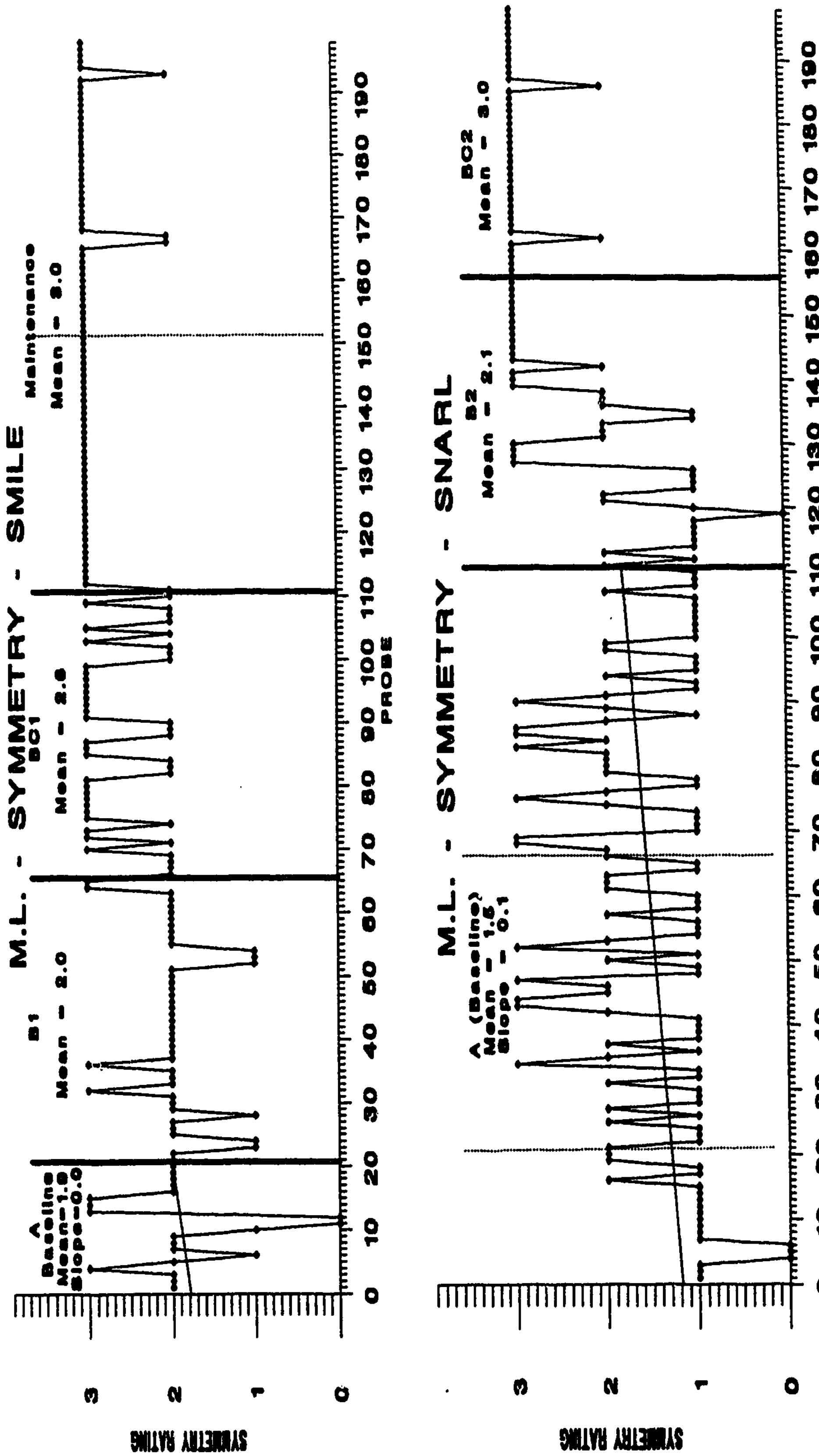

Figure 2-B. Symmetry ratings of subject M.L. for each photograph across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

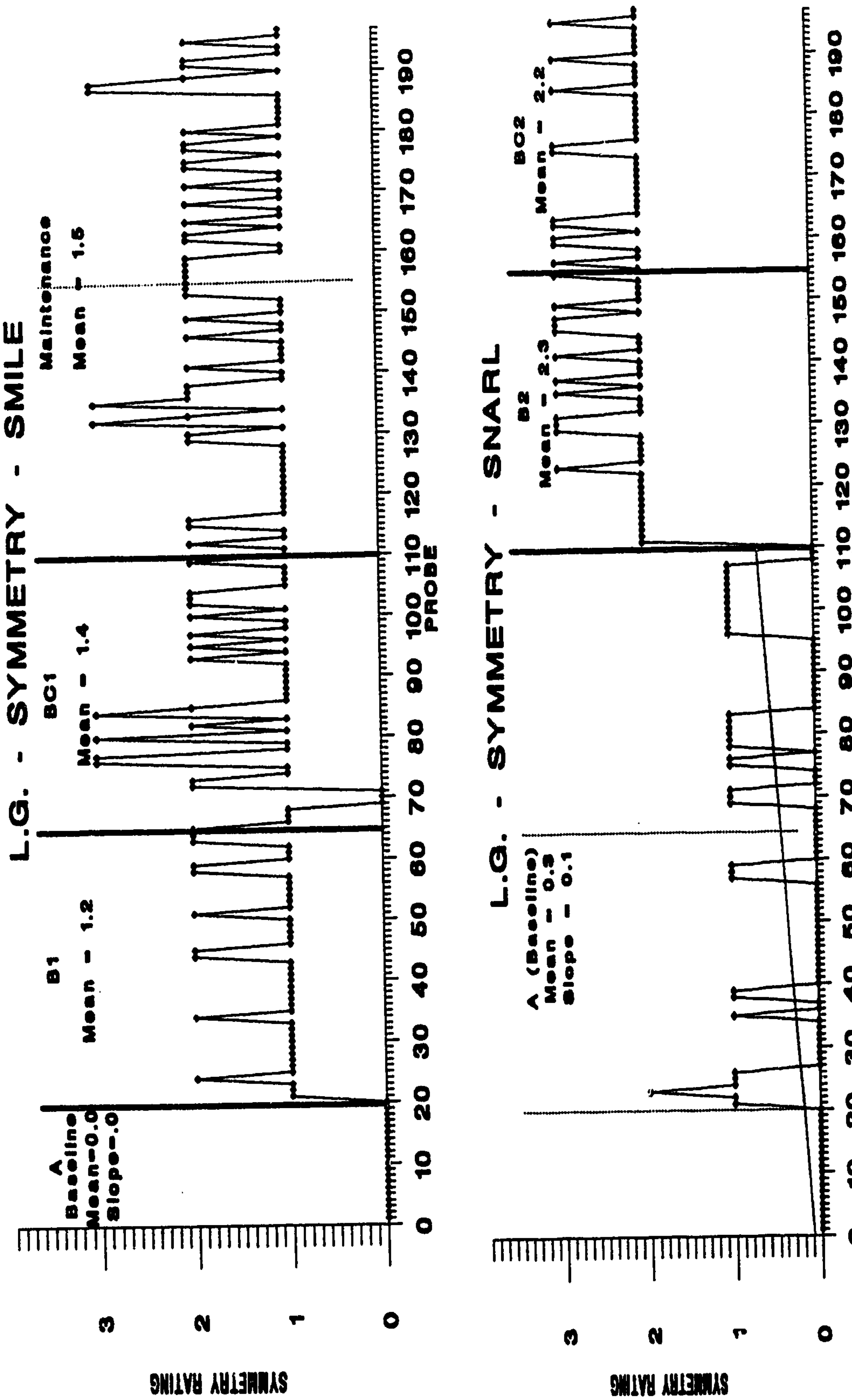

Figure 2-C. Symmetry ratings of subject L.G. for each photograph across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

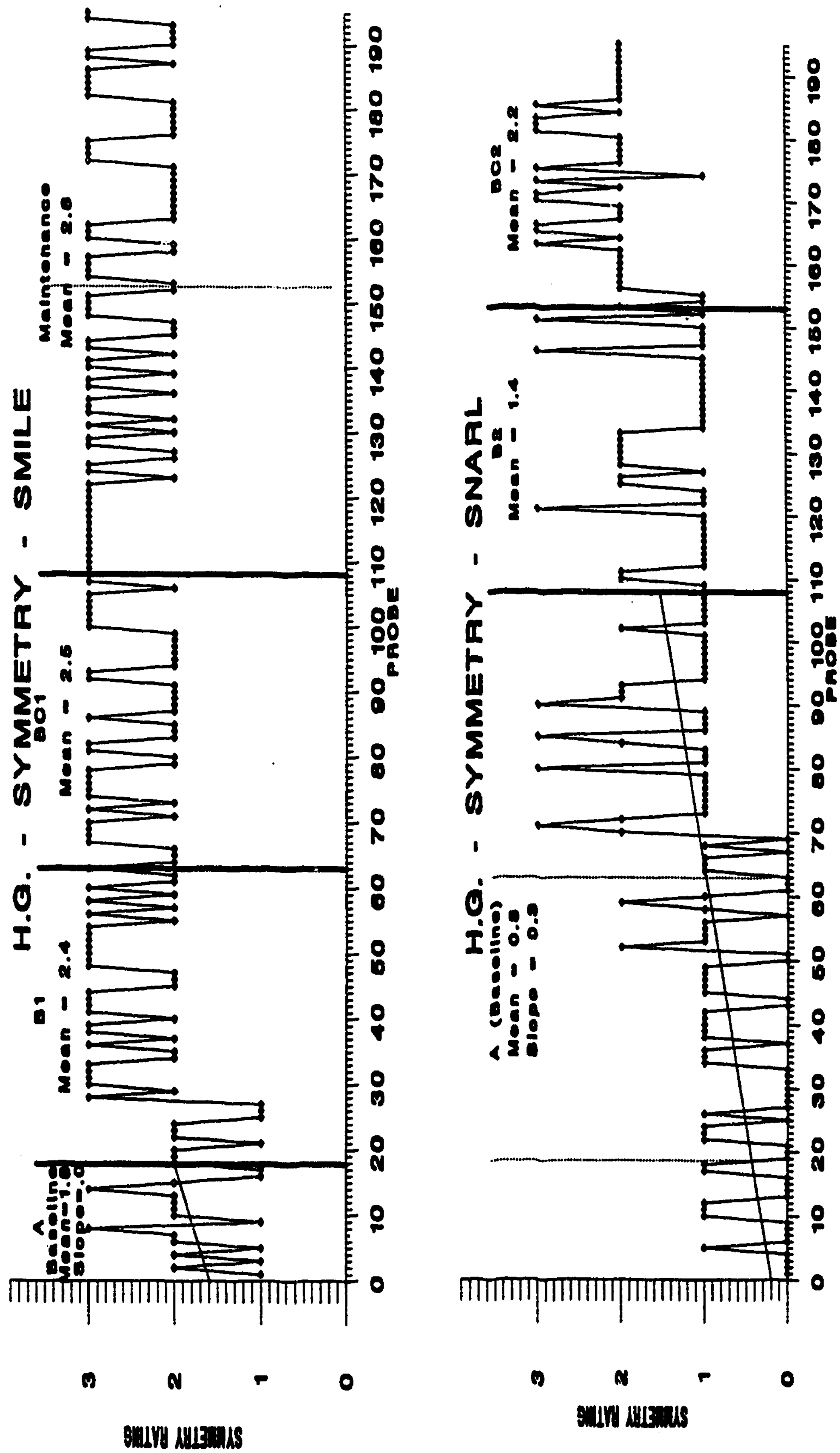

Figure 2-D. Symmetry ratings of subject H.G. for each photograph across all experimental conditions for the "smile" (upper graph) and the "snarl" (lower graph) target behaviors.

Figure 2-D illustrates the symmetry ratings for subject H.G. for both facial gestures. As shown by the "smile" symmetry data graphed at the top of the figure, he exhibited an unstable baseline (mean rating = [illegible]). His mean symmetry rating increased with the application of mirror feedback (phase B1; mean rating = 2.4), and remained stable thereafter during the application of both treatments (phase BC1; mean rating = 2.5) and during the maintenance period (mean rating = [illegible]5). Data for the prolonged baseline phase for the "snarl" gesture, in the lower portion of the figure, exhibited an unstable baseline (mean rating = 0.8); symmetry ratings increased toward the end of the baseline. His facial symmetry during the application of mirror feedback for the "snarl" (phase B2; mean rating = 1.4) was rated similarly to that near the end of baseline for this gesture; ratings increased during the application of both treatments (phase BC2; mean rating = 2.2). This subject exhibited an overall increase in symmetry ratings during treatment compared to baseline for both facial muscle gestures. A between-treatment difference in mean symmetry scores is apparent for his "snarl" data only.

In summary, the symmetry rating data derived from the 5" x 7" color photographs of subjects' productions of "smile" and "snarl" gestures across the experimental period were characterized by the following features: (1) all subjects exhibited an overall increase in symmetry ratings at some time during treatment, compared to baseline data; (2) between-treatment differences were exhibited in the "smile" data obtained from three of the four subjects; (3) between-treatment differences were exhibited in the "snarl" data obtained from three of the four subjects. Whether the B1 versus BC1 and B2 versus BC2 differences in mean "ramp function" accuracy scores constitute a between-treatments effect is equivocal, however. This issue will be addressed in the Discussion chapter.

Correlations

Spearman Rank-Order correlations (Bruning & Kintz, 1977) were used to examine the relationship between the accuracy of facial EMG "ramp functions" and the symmetry ratings of corresponding photographs for the "smile" and "snarl" gestures. The relationship between photograph symmetry ratings and the amplitude ratios of the corresponding bilateral EMG records was examined in a similar manner. Comparisons were based on all of the data collected across the 13-week period of the study. Table 6 (A & B) illustrates the correlations between these variables. Table 6-A describes the comparisons between EMG "ramp function" percent accuracy scores (lowest to highest, 0 - 100) and symmetry ratings (asymmetrical to symmetrical, 0 - 3). A negative correlation implies that EMG "ramp function" accuracy was high when photographic symmetry ratings were low, or *vice versa*, that EMG "ramp function" accuracy was low when photographic symmetry ratings were high. A positive correlation implies that "ramp function" accuracy was high when symmetry ratings were high, or, that both "ramp function" accuracy and symmetry ratings were low. Table 6-B describes the comparisons between amplitude ratios of bilateral electromyograms (low to high) and photograph symmetry ratings (asymmetrical to symmetrical, 0 - 3). A low ratio implies that amplitude values for the weak side of the face, during the hold phase of a "smile" or "snarl," were lower than amplitude values for the strong side of the face (e.g., 4μV[weak]/10μV[strong]); a high ratio implies that amplitude values for the weak side of the face were higher than amplitude values for the strong side of the face (e.g., 5μV[weak]/4μV[strong]). A negative correlation implies that amplitude ratios were high when symmetry ratings were low, or vice versa. A positive correlation implies that amplitude ratios were high when symmetry ratings were high, or that corresponding ratios and symmetry ratings both were low.

Table 6-A. Correlations between "ramp function" percent accuracy scores from facial electromyograms and corresponding symmetry ratings for photographs of "smile" and "snarl" obtained across the duration of the experiment. (* significant at the 0.05 level; ** significant at the 0.01 level)

Subject	Facial Behavior	Rho (corrected for ties)	t statistic (corrected for ties)	Degrees of Freedom
E.H.	smile	.282	* 4.12	197
M.L.	smile	.034	.476	197
L.G.	smile	-.115	* -1.975	196
H.G.	smile	.257	** 3.69	194
E.H.	snarl	.238	** 3.43	197
M.L.	snarl	.174	2.473	197
L.G.	snarl	-.153	* -2.162	196
H.G.	snarl	.412	** 6.28	194

With reference to the data in Table 6-A, three correlations were significant at the 0.05 level, for subjects L.G. ("smile" & "snarl") and E.H. ("smile"). Three correlations were significant at the 0.01 level, for subjects H.G. ("smile" & "snarl") and E.H. ("snarl"). All significant correlations were positive with the exception of those for L.G.; that is, her "ramp function" accuracy was high while the symmetry ratings for the photographs that corresponded to the stable hold portion of the "ramp function" data were low.

Table 6-B. Correlations between amplitude (μV) ratios of bilateral facial electromyograms and symmetry ratings for corresponding photographs of "smile" and "snarl" obtained across the duration of the experiment. (* significant at the 0.05 level; ** significant at the 0.01 level).

Subject	Facial Behavior	Rho (corrected for ties)	t statistic (corrected for ties)	Degrees of Freedom
E.H.	smile	.169	* 2.40	197
M.L.	smile	.08	1.124	197
L.G.	smile	-.054	-.755	196
H.G.	smile	.144	2.02	194
.E.H.	snarl	.341	** 5.078	197
M.L.	snarl	-.034	-.476	197
L.G.	snarl	-.261	** -3.775	196
H.G.	snarl	-.191	** -2.70	194

Among the results of the correlational analyses presented in Table 6-B, one was significant at the 0.05 level, (E.H., "smile"), and three were significant at the 0.01 level ("snarl" comparisons for L.G., H.G. & E.H.). Among these significant relationships, two were negative; that is, for L.G. and H.G. amplitude ratios during the treatment of the "snarl" were high while photograph symmetry ratings were low.

In summary, when comparisons were made between facial EMG "ramp function" accuracy and symmetry ratings of corresponding photographs, six of the eight correlations (four each associated with the "smile" & the "snarl" data) were statistically significant. Six correlations were positively correlated and two were negatively correlated. When comparisons were made between the amplitude ratios of bilateral facial electromyograms and symmetry ratings of the corresponding photographs, four of the eight correlations were statistically significant. Two correlations were positively correlated and two were negatively correlated.

Reliability

Electromyographic data. Interjudge reliability is tabulated in Table 7. The table includes interjudge agreement values between both judges' evaluations of the "smile" and "snarl" target behaviors for all subjects. The highest interjudge agreement was exhibited for electromyogram evaluations of subjects E.H. and L.G. for the "smile" (70%) and "snarl" (75%) target gestures respectively. The lowest interjudge agreement ratings were exhibited for electromyogram evaluations of subjects M.L. and H.G. (65%) for both the "smile" and "snarl" target gestures. The 10% difference between the lowest and highest interjudge agreement values is accounted for by two electromyograms (agreement on 15/20 electromyograms versus 13/20).

Table 7. Interjudge reliability, reported as overall agreement between both judges' ratings of 40 electromyograms associated with "smile" and "snarl" gestures for 10.25% of each subject's data base (160 electromyograms).

SUBJECT	FACIAL BEHAVIOR	% AGREEMENT
E.H.	smile	70%
M.L.	smile	65%
L.G.	smile	70%
H.G.	smile	65%
E.H.	snarl	75%
M.L.	snarl	65%
L.G.	snarl	75%
H.G.	snarl	65%

Intrajudge reliability for repeated ratings is tabulated in Table 8 for the "smile" gesture and Table 9 for the "snarl" gesture.

Table 8. Intrajudge reliability reported as overall percent agreement for each judge's repeated ratings of 4 electromyograms for the "smile" gesture of each subject.

	Subject 1 (E.H.)	Subject 3 (M.L.)	Subject 4 (L.G.)	Subject 2 (H.G.)
Judge 1	75%	100%	100%	75%
Judge 2	75%	75%	100%	75%

Table 9. Intrajudge reliability reported as overall percent agreement for each judge's repeated ratings of 4 electromyograms for the "snarl" gesture of each subject.

	Subject 1 (E.H.)	Subject 3 (M.L.)	Subject 4 (L.G.)	Subject 2 (H.G.)
Judge 1	75%	100%	100%	75%
Judge 2	75%	75%	100%	75%

Photographic data. Interjudge reliability is tabulated in Table 10. The table includes percent agreement values among all the judges' symmetry ratings of the "smile" and "snarl" target behaviors for all subjects. The highest interjudge agreement ratings were exhibited for symmetry ratings of judge #1, the primary investigator, and judge #3, an external judge, for both the "smile" and "snarl" gestures. In contrast, the lowest total reliability ratings were exhibited when agreement was calculated among judges #1, #2 and #3.

Table 10. Interjudge reliability reported as overall agreement among all the judges' symmetry ratings of 160 photographs associated with "smile" and "snarl" gestures for 10.25% of each subject's data base.

SUBJECT	FACIAL BEHAVIOR	JUDGES	% AGREEMENT
E.H.	smile	1, 2 & 3	33%
M.L.	smile	1, 2 & 3	15%
L.G.	smile	1, 2 & 3	30%
H.G.	smile	1, 2 & 3	45%
E.H.	smile	2 & 3	56%
M.L.	smile	2 & 3	20%
L.G.	smile	2 & 3	50%
H.G.	smile	2 & 3	65%
E.H.	smile	1 & 2	44%
M.L.	smile	1 & 2	60%
L.G.	smile	1 & 2	56%
H.G.	smile	1 & 2	55%
E.H.	smile	1 & 3	61%
M.L.	smile	1 & 3	35%
L.G.	smile	1 & 3	56%
H.G.	smile	1 & 3	67%
E.H.	snarl	1, 2 & 3	50%
M.L.	snarl	1, 2 & 3	25%
L.G.	snarl	1, 2 & 3	39%
H.G.	snarl	1, 2 & 3	25%
E.H.	snarl	2 & 3	61%
M.L.	snarl	2 & 3	35%
L.G.	snarl	2 & 3	44%
H.G.	snarl	2 & 3	35%
E.H.	snarl	1 & 2	56%
M.L.	snarl	1 & 2	50%
L.G.	snarl	1 & 2	50%
H.G.	snarl	1 & 2	40%
E.H.	snarl	1 & 3	83%
M.L.	snarl	1 & 3	50%
L.G.	snarl	1 & 3	70%
H.G.	snarl	1 & 3	65%

Intrajudge reliability for repeated ratings is tabulated in Table 11 for the "smile" gesture and Table 12 for the "snarl" gesture.

Table 11. Intrajudge reliability reported as overall percent agreement for each judge's repeated ratings of 4 photographs of the "smile" gesture for each subject.

	Subject 1 (E.H.)	Subject 3 (M.L.)	Subject 4 (L.G.)	Subject 2 (H.G.)
Judge 1	50%	100%	75%	75%
Judge 2	50%	100%	100%	100%
Judge 3	72%	88%	80%	76%

Table 12. Intrajudge reliability reported as overall percent agreement for each judge's repeated ratings of 4 photographs of the "snarl" gesture for each subject.

	Subject 1 (E.H.)	Subject 3 (M.L.)	Subject 4 (L.G.)	Subject 2 (H.G.)
Judge 1	100%	75%	100%	100%
Judge 2	100%	100%	100%	75%
Judge 3	88%	76%	84%	76%

CHAPTER IV. DISCUSSION

The primary purpose of this research was to examine the differential effectiveness of mirror training alone and mirror training plus EMG feedback on 1) patients' ability to produce electromyographic "ramp functions" according to specified criteria, and 2) their ability to produce visibly symmetrical facial gestures. Symmetry ratings and "ramp function" accuracy measures were obtained for "smile" and "snarl" target gestures before and during facial muscle treatment of four adult subjects with unilateral facial paresis. The relationships between "ramp function" accuracy and symmetry ratings of corresponding specific perioral muscle gestures, and between facial symmetry ratings and corresponding bilateral facial surface electromyograms were investigated. The results of this study will be discussed relative to the six research questions posed. Clinical implications of the results, limitations of the investigation and suggestions for future research also will be presented.

Research question number one asked whether the application of mirror training alone, compared to no treatment, improved the accuracy of EMG "ramp functions" corresponding to the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage.

Research question number two asked whether the application of mirror training alone, compared to no treatment, improved symmetry ratings assigned to photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage.

Mirror Training Effects

Results from the present study indicate that three of the four subjects exhibited improvements in "ramp function" accuracy for both the "smile" and "snarl" gestures during the application of mirror training compared to baseline. Improvement was based on changes in the "ramp function" accuracy data associated with the subjects' ability to: (1) initiate the target gesture with the weak side of the face; (2) produce the gesture continuously and slowly; (3) stabilize the target gesture when it appeared visibly symmetrical in a mirror; and (4) abruptly release all muscle groups involved in the production of the target gesture. "Improvement" in this context refers to an increase in "ramp function" accuracy between the baseline and "mirror-only" experimental phases. Improvement between the baseline and mirror treatment phases ranged from 10 to 20% across three subjects. The fourth subject (L.G.) failed to show improved "ramp function" accuracy scores for the two target gestures; in fact her accuracy deteriorated by 10% for both the "smile" and "snarl" gestures during the application of mirror training. Thus, her "ramp function" accuracy scores were higher during baseline than during treatment, for both behaviors, compared to the response patterns of the three other subjects.

With respect to the photograph symmetry data, results from the present study indicate that all four subjects exhibited improvements in mean symmetry ratings for both the "smile" and "snarl" gestures during the application of mirror training compared to their baseline performances. "Improvement" refers to the appearance of higher mean symmetry ratings when mirror training was applied, compared to the mean symmetry ratings assigned to photographs of the target gestures during baseline. Improvement between the baseline and mirror treatment phases ranged from 0.1 to 2.0 points on the 4-point symmetry rating scale. The most noticeable improvements in symmetry ratings, 0.6 to 2.0 points, were shown in the data for three subjects (E.H., L.G. & H.G) for both target gestures and in the fourth subject's data (M.L.) for the "snarl" gesture.

Research question number three examined whether the application of EMG feedback in conjunction with mirror training, compared to the application of mirror training alone, or no training, improved the accuracy of EMG "ramp functions" corresponding to the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage.

Research question number four examined whether the application of EMG feedback in conjunction with mirror training, compared to the application of mirror training alone, or no training, improved symmetry ratings assigned to photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage.

Mirror-Plus-EMG Training Effects

"Ramp function" accuracy data are discussed relative to differences in mean symmetry ratings between baseline and "mirror-only" training and between "mirror-only" and "mirror-plus-EMG" training. "Improvement" between baseline and the "mirror-plus-EMG" phases refers to an increase in the mean accuracy scores for the BC phase compared to mean "ramp function" accuracy during the initial baseline phase and ranged from 10 to 30%. Data for three of the four subjects (E.H., M.L. & H.G.) revealed improvement in mean "ramp function" accuracy with the application of "mirror-plus-EMG" treatment compared to baseline for both gestures. "Improvement" between the "mirror-only" and "mirror-plus-EMG" treatment phases refers to an increase in the mean "ramp function" accuracy scores for the BC phase compared to mean "ramp function" accuracy during the preceding B phase and ranged from 10 to 20%. "Ramp function" accuracy increased for both target gestures with the addition of EMG feedback to mirror training for two subjects (E.H. & H.G.) and for one target gesture only ("smile") for the two other subjects (M.L. & L.G.). "Ramp function" accuracy stabilized for the latter subjects for the "snarl" gesture. That is, in six of eight BC training opportunities, subjects' mean "ramp function" accuracies increased when the subjects were provided with visible analogs of EMG feedback in addition to mirror training. A between-treatments difference was not consistent across subjects nor across gestures, however.

Overall, mean "ramp function" accuracy measures were higher for both gestures across three subjects during the "mirror-plus-EMG" treatment phase when compared to baseline. Mean "ramp function" accuracy measures were higher during the application of both treatments compared to "mirror-only" training for six out of eight training opportunities.

Photograph symmetry data are discussed relative to differences in mean symmetry ratings between baseline and "mirror-only" training and between "mirror-only" and "mirror-plus-EMG" training. "Improvement" between baseline and the "mirror-plus-EMG" phases refers to an increase in the mean symmetry ratings for the BC phase compared to ratings during the preceding baseline phase and ranged from 0.7 to 2.1 points on the 4-point symmetry rating scale. Data for all subjects revealed improvement in symmetry ratings with the application of "mirror-plus-EMG" treatment compared to baseline. "Improvement" between the "mirror-only" and "mirror-plus-EMG" treatment phases refers to an increase in the mean symmetry ratings for the BC phase compared to symmetry ratings during the preceding B phase and ranged from 0.1 to 0.9 points on the 4-point symmetry rating scale. With the exception of the "smile" gesture for subject H.G. and the "snarl" gesture for subject L.G., the addition of EMG feedback to mirror training produced results indicating improved mean symmetry ratings during the "mirror-plus-EMG" phases compared to the "mirror-only" treatment phases for all subjects. Two subjects (E.H. & M.L.) showed improvements in their mean symmetry ratings for both the "smile" and "snarl" target gestures during the application of mirror-plus-EMG treatment compared to the application of mirror training alone. Of the remaining two subjects, one subject (H.G.) showed improvements in his mean symmetry ratings for one target gesture only during the BC phase, and the other subject (L.G.) failed to show any improvement with the application of both treatments compared to mirror training. For two subjects, M.L. ("smile" & "snarl") and H.G. ("snarl"), the symmetry rating difference between the application of both treatments and mirror training alone was larger than the difference between the application of mirror training alone and baseline.

Overall, mean symmetry ratings were higher during the "mirror-plus-EMG" treatment phase when compared to baseline for both gestures across all subjects who participated in the study. Mean symmetry ratings were found to be higher during the application of both treatments compared to "mirror-only" training for six out of the eight training opportunities.

Correlations

Research question number five examined the relationship between the accuracy of facial EMG "ramp functions" and the symmetry ratings of corresponding photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage. Comparisons were made between the electromyographic data and photographic data using Spearman Rank-Order correlations (Bruning & Kintz, 1977).

The correlation results for research question number five are illustrated in Table 6A, p. 68. In total, six out of eight correlations (four each associated with the "smile" & the "snarl" data) were statistically significant. Two of the three correlations associated with the "smile" data and the same number associated with the "snarl" data revealed positive correlations suggesting that when the "ramp function" accuracy was high, the corresponding photographic symmetry ratings also were high, near the symmetrical end of the rating scale. The remaining correlations for the "smile" and "snarl" data were negative implying that when "ramp function" accuracy was high, corresponding photographic symmetry ratings were low, near the asymmetrical end of the rating scale.

Research question number six examined the relationship between the amplitude ratios of bilateral facial electromyograms and the symmetry ratings of corresponding photographs of the performance of "smile" and "snarl" facial gestures by patients with unilateral facial paresis due to peripheral nerve damage. Comparisons were made between the electromyographic data and photographic data using Spearman Rank-Order correlations (Bruning & Kintz, 1977).

The correlation results for research question number six are illustrated in Table 6-B, p. 69. Overall, four out of eight correlations (four each associated with the "smile" & the "snarl" data) were statistically significant. One correlation associated with the "smile" data and one correlation associated with the "snarl" data revealed positive correlations reflecting the fact that when amplitude ratios of bilateral facial electromyograms were high (i.e., weak side amplitudes were higher than strong side amplitudes), corresponding photographic symmetry ratings were closer to the symmetrical end of the rating scale. The remaining two correlations associated with the "snarl" data were negative, implying that when amplitude ratios of bilateral facial electromyograms were high, corresponding photographic symmetry ratings were low, near to the asymmetrical end of the rating scale.

Instances of statistical significance found in the results of research questions five and six are likely due to the relatively large data pool. Their statistical significance notwithstanding, all the correlations were weak suggesting that the relationships accounted for only a limited portion of the experimental variance in the data. A few possible explanations for the low correlations may be offered. One explanation for the weak relationship between the facial symmetry and "ramp function" ratings is that they represent different aspects of the facial behavior of interest. These two variables may not be highly-related because the ratings of a "ramp function" include judgements about four aspects of a behavior (i.e., onset, ramp, amplitude hold & release) across a period of time, whereas the photograph symmetry ratings correspond to only a moment of that behavior in time (somewhere during the "hold"). Thus, the assumption that good performance of all aspects of a "ramp function" is related to ultimate achievement of visible facial symmetry was not supported by the data of this study. Another explanation for the weak relationship between the facial symmetry and "ramp function" ratings is related to the fact that subjects took their own pictures once they judged the target behavior to be symmetrical as it appeared in the mirror. It is possible, therefore, that a discrepancy existed between the subjects' and judges' perceptions of facial symmetry. Inferences also have been made in the literature suggesting that a correspondence exists between facial symmetry and bilaterally equivalent EMG amplitude levels. The assumption that these two variables correspond with one another was not supported by the data of this study. Explanations for the weak relationship between facial symmetry and bilateral EMG amplitude ratios are moot because correlations between these two variables have yet to be investigated in individuals who have not suffered facial nerve trauma; therefore, it is not known whether these two variables should be highly related. Another issue that is relevant to the low correlations between facial symmetry and "ramp function" data as well as those between facial symmetry and EMG amplitude ratios is that the "smile" and "snarl" gestures were not very large, even near the end of the 13-week period, and the range of excursion did not change very much across time. Therefore, judges had difficulty making valid judgements, and a consensus on the photograph symmetry ratings across the three judges was difficult to achieve. As is displayed in Table 10 (p. 72) interjudge reliability was poor for this rating task, indicating that the judges were unable to perceive facial symmetry in the "smile" and "snarl" photographs consistently among themselves. The results of the interjudge reliability data suggest, therefore, that the photograph symmetry rating task had limited utility as a dependent measure in this study.

In summary, results have been presented which examined the effects of two forms of facial muscle retraining, mirror training and mirror training in conjunction with EMG feedback on individuals with unilateral facial paresis. Additionally, correlations were made between "ramp function" accuracy and the symmetry ratings of corresponding photographs and between amplitude ratios of bilateral facial electromyograms and the symmetry ratings of corresponding photographs of the performance of "smile" and "snarl" facial gestures. Results indicate that three of the four subjects exhibited improvements in "ramp function" accuracy for both the "smile" and "snarl" gestures during the application of mirror training. With respect to the photograph symmetry data, results indicate that with the exception of data associated with one subject for one behavior all four subjects exhibited improvements in mean symmetry ratings for both target behaviors during the application of mirror training compared to their baseline performances. Comparisons between the interaction treatment phase and baseline phase indicated that mean "ramp function" accuracy measures were higher for both gestures across three subjects. Mean symmetry ratings were higher during the "mirror-plus-EMG" treatment phase when compared to baseline for both gestures across all subjects who participated in the study. With respect to the interaction treatment phase compared to mirror training only, subjects' mean "ramp function" accuracies increased when the subjects were provided with visible analogs of EMG feedback in addition to mirror training in six of eight BC training opportunities. A between-treatments difference was not consistent across subjects or across gestures, however. Mean symmetry ratings were found to be higher during the application of both treatments compared to "mirror-only" training for six out of the eight training opportunities. From the results of this study, no conclusions could be made that one form of treatment was more potent than another. Although significant positive correlations were found to exist between photographs of facial symmetry and "ramp function" accuracy and between facial symmetry and amplitude ratios of bilateral facial electromyograms, all correlations were weak and their significance marred by other sources of experimental variance (i.e., range of gestural excursion was minimal across time, hence interjudge reliability was poor for the photograph symmetry rating task).

Limitations of the Present Study and Suggestions for Future Research

The results of this investigation showed an overall treatment difference compared to the baseline data for all subjects for the "smile" gesture and for three subjects for the "snarl," either when mirror training was compared to baseline or when mirror training plus EMG feedback was compared to baseline. Design and procedural limitations render it impossible to determine if one treatment condition was more potent than another, however. In the text that follows a number of those limitations will be discussed including the fact that: (1) baseline data were generally variable across the four subjects; (2) baseline contamination was not controlled for by treatment order counterbalancing; (3) duration of the treatment phases was limited; (4) time constraints precluded within-subject replication; (5) the presence of ceiling effects prevented an accurate indication of extent of changes in facial symmetry across the duration of the study; and (6) threats to both internal and external validity existed in the present investigation.

Baseline Stability

A stable baseline provides a strong foundation for comparison of subsequent response patterns associated with treatment. Ideally, one should obtain a stable baseline response to ensure that the behavior to be measured is not changing prior to the initiation of treatment. Additionally, a stable series of baseline observations makes interpretation and analysis of the data collected during treatment phases much easier. Unfortunately, obtaining a stable baseline is often a difficult task when one is dealing with behaviors associated with human subjects (Barlow & Hersen, 1984; McReynolds & Kearns, 1983; Ottenbacher, 1986).

With respect to the present study, baselines established for "ramp function" accuracy were generally variable. Baseline data were considered variable (unstable) if the data exhibited a noticeable trend toward increasing "ramp function" accuracy scores or if trend lines reflected a change that exceeded 10% based on the "ramp function" percent accuracy scale. Baseline variability was the norm; only two subjects (E.H. & H.G.) exhibited stable baselines for the first treatment gesture, "smile;" all subjects exhibited variable prolonged baselines for the "snarl" gesture.

With respect to the photograph symmetry data, baselines associated with ratings for the two target gestures across the four subjects were considered unstable if variability in the rating data exceeded a one-point spread on the 4-point symmetry rating scale across a given baseline (data series that exhibited one or two outliers only in a given baseline were considered stable). This criterion was chosen because the scale restricted judges' response options for variations in facial symmetry that were small; day-to-day variability during baseline may have been noticeable enough to warrant a rating for one photograph that differed by one point from that of another baseline photograph. The scale was likely narrower than judges' perceptual ranges for the appreciation of day-to-day symmetry changes. Baseline variability was exhibited more frequently in the "ramp function" data than in the symmetry rating data; three subjects (E.H., L.G. & H.G.) exhibited stable baselines for the first treatment gesture, "smile" and two subjects (E.H. & L.G.) exhibited stable baselines for the "snarl" gesture. Variability in the prolonged baseline data for subjects M.L. and H.G. is related to contamination by the training effect occurring during "smile" treatment. The baseline data associated with subject L.G. were stable for her "smile" and "snarl" gestures.

Overall, nine out of sixteen baseline series (eight each for "ramp function" accuracy & symmetry ratings) were considered to be variable. Therefore, evaluations of patterns in the data based on visual comparison of the baseline and treatment phases are less than reliable (Barlow & Hersen, 1984; McReynolds & Kearns, 1983; Ottenbacher, 1986).

Interdependence of Treatment and Concomitant Baselines

When one or more data series are interdependent, so that change in one behavior with the application of treatment carries over to another behavior, prior to the initiation of intervention for that behavior, generalization across behaviors may occur, and the specific effect of the intervention on any one behavior becomes ambiguous (Kazdin, 1982). Kazdin suggests that a specific intervention, or treatment condition in this context, can account for multiple behavior changes, even though intervention is applied only to one behavior at a time. Kazdin also indicates that extraneous events possibly may coincide with the application of treatment and may be responsible for general changes in performance. The primary concern when these conditions occur is that the results of intervention become ambiguous.

The results of this investigation reveal evidence of generalization or contamination across the data series for "smile" and "snarl" in some subjects. That is, generalization of treatment of one gesture often was apparent in the data for the performance of the other gesture, such that application of training to "smile" may have affected the prolonged baseline of "snarl," and application of training to "snarl" may have affected data for the maintenance phase of "smile."

The "ramp function" accuracy data for the prolonged baseline period associated with the "snarl" gesture appeared to be contaminated by the treatment of the "smile" gesture in all four subjects. The onset of signs of contamination varied across the subjects, however. Whereas evidence of contamination appeared early in the baseline phase for "snarl" in three subjects (M.L., L.G., & H.G.), contamination effects did not appear until late in the prolonged "snarl" baseline of subject E.H..

With respect to the photograph symmetry data, two of the four subjects (M.L. & H.G.) exhibited spontaneous improvement in symmetry ratings during the prolonged baseline period associated with the "snarl" gesture. This improvement suggests contamination of the performance of "snarl" during its prolonged baseline by the training being applied to the "smile" gesture. Of the two subjects who exhibited baseline contamination, subject M.L. displayed symmetry rating improvement early in her "snarl" baseline phase, whereas subject H.G. did not reveal evidence of contamination until half-way through his "snarl" baseline phase.

The data for the prolonged maintenance phase associated with the "smile" gesture exhibited spontaneous improvement in "ramp function" accuracy for one subject only (H.G.). This improvement may be attributable to contamination by the training being applied to the "snarl" gesture during the maintenance phase of the "smile." The remaining three subjects exhibited stable data during the maintenance phase for the "smile" gesture, suggesting that the treatment applied to the "snarl" gesture had minimal effect on the untrained "smile" gesture. Additionally, it is possible that ceiling effects limited opportunities to see contamination effects in maintenance phases.

The photograph symmetry rating data for the maintenance phase associated with the "smile" gesture exhibited improvement in symmetry ratings for one subject only (M.L.). This improvement may be attributable to a contamination effect on the "smile" data by the application of treatment to the levator muscle group for the "snarl" gesture. The remaining three subjects exhibited stable maintenance phases for the "smile" gesture.

In summary, all subjects revealed evidence of contamination in the "ramp function" data, and two subjects exhibited contamination effects in the symmetry data during the prolonged baseline phase of the "snarl" target gesture. During the prolonged maintenance phase for the "smile" gesture, one subject's data associated with "ramp function" accuracy and one subject's data associated with symmetry ratings displayed evidence of contamination. It appears that baseline of an as yet untrained behavior may be more vulnerable to contamination than the maintenance phase of an already trained behavior.

Counterbalancing

Whenever more than one treatment is administered or more than one behavior is treated sequentially, data may be influenced by order effects (McReynolds & Kearns, 1983; Ottenbacher, 1986).

Treatment order was not counterbalanced in the present investigation; the "mirror-only" treatment phase always preceded the "mirror-plus-EMG" treatment phase. Therefore, opportunity for a treatment order effect was not controlled in this investigation. Additionally, the "smile" target gesture was always trained prior to the "snarl" gesture, indicating that there was a risk of a behavior order effect on the results.

Treatment order effects can be controlled in multiple-baseline studies via counterbalancing the interventions (McReynolds & Kearns, 1983; Ottenbacher, 1986). Thus, in the existing study, counterbalancing the "mirror-only" and "mirror-plus-EMG" treatment phases could control for possible order effects resulting from the former treatment phase always preceding the latter. Counterbalancing treatment order would have provided the investigator with data associated with the provision of "mirror-only" preceding "mirror-plus-EMG" and "mirror-plus-EMG" preceding "mirror-only." Treatment order counterbalancing would have helped the investigator address several issues, such as: (1) did the provision of "mirror-only" treatment influence the data corresponding to the "mirror-plus-EMG" treatment phase; (2) would improvements exhibited during the combined treatment phase be similar during the "mirror-only" treatment phase if "mirror-plus-EMG" preceded "mirror-only" treatment; and (3) was improvement exhibited during the combined treatment phase actually due to the addition of EMG feedback, or was it associated with the increased duration of training. That is, did the additional three weeks of treatment influence the results as much as the type of treatment administered. Counterbalancing the order of the behaviors would have helped the investigator examine the influence of behavior order on baseline and maintenance phase contamination; behavior order may have contributed to the apparent contamination exhibited during these phases. Four additional subjects would have been required to counterbalance treatment order effects and four more subjects would have been required to counterbalance the order of the behaviors. Unfortunately, only four subjects volunteered to participate in the present study and therefore the principal investigator chose not to counterbalance for either treatment order or behavior order effects. Future studies that also exhibit such a limited number of subjects may chose to counterbalance for treatment order by dividing the subjects into two groups. Thus, two subjects could receive application of mirror training alone followed by application of mirror training in conjunction with EMG feedback and the remaining two subjects could receive application of mirror training in conjunction with EMG feedback followed by application of mirror training alone.

Treatment Duration

As alluded to in the previous paragraph, it is possible that the results associated with the "mirror-only" and "mirror-plus-EMG" treatment conditions may have been different, not only if the treatment order was counterbalanced, but also if the length of the respective treatment phases had been longer in duration. Subjects received 3 weeks each of the two treatment conditions for the two target gestures, "smile" and "snarl." The design of this study prevented the investigator's concluding whether similar trends in the data would exist had the subjects received 6-weeks of mirror training only, 6-weeks of mirror training-plus-EMG only, or 6-weeks of mirror training followed by the combined treatment condition for the same duration. Additionally, the investigator would have been better able to monitor carry-over effects between treatment phases that could have occurred in the absence of treatment order counterbalancing had the treatment phases been longer in duration and had a changing criterion performance been utilized.

Within-subject Replication

Within-subject replication, one of two categories of direct replication, refers to replication of the therapeutic process or comparison on the same client. Repetition of the same treatment sequence in the same subject adds to the reliability of a given treatment if results from the second administration parallel those of the first (Barlow & Hersen, 1976; McReynolds & Kearns, 1983; Ottenbacher, 1986; Sidman, 1960).

Although between-subject replication was an integral component of the multiple-baseline design in this study, within-subject replication was not included due to the time constraints of the investigation. Evidence of treatment effectiveness is therefore limited because neither the "mirror-only" nor the "mirror-plus-EMG" treatment phases were repeatedly applied to the same subject across the same target behavior. It is possible, that within-subject replication may have yielded limited information because ceiling effects may have restricted opportunities to see changes in the data upon application of a given treatment phase for the second time. Regardless, the range of subject variability for possible treatment success is restricted without the provision of within-subject replication. Hence, future studies that are longer in duration than the present study may benefit from employing within-subject replication with a changing performance criterion.

Ceiling Effects

A ceiling effect occurs when the performance of a given task, in this case the production of "smile" and "snarl" facial gestures reaches the upper end of the performance rating index (Ottenbacher, 1986). Without some change in the definition of the performance, its rating scale or its extent, it is not possible to track further change in the performance. The experimental design and limited duration of this study contributed to the opportunity for such an effect in the data of some subjects; they reached a "ceiling" on the symmetry rating scale prior to the termination of treatment in the BC phase or during the maintenance phase. Because there was no opportunity to redefine the performance criteria for the facial gestures and replicate treatments within the experimental period, the maximum benefits of the BC phase may have been masked. One method in particular could be used in future research of this kind to avoid such ceiling effects. Some form of change in performance criterion, possibly utilizing a changing criterion design (McReynolds & Kearns, 1983; Ottenbacher, 1986), could be applied within or between experimental phases so that subjects increase systematically the excursion of their "smile" or "snarl" gestures. Such a design would allow for extended range of motion of the target behaviors each time a subject reached a predetermined criterion. Symmetrical control then would be required for this new behavioral target, thereby refreshing the utility of the 4-point symmetry rating scale and avoiding the ceiling effect that was observed in some of the data presented.

Threats to Internal Validity

Internal validity refers to the extent to which manipulation of an independent variable is responsible for or caused changes in the dependent variable(s) (Campbell & Stanley, 1963; Ottenbacher, 1986; Smith & Glass, 1987).

History, maturation and test-practice effects in particular are factors that could be applicable to this investigation, because they are threats associated with multiple measures of a dependent variable for one subject (Campbell & Stanley, 1963; Ottenbacher, 1986; Smith & Glass, 1987). Historical factors can either have occurred prior to the initiation of an experiment or exist during the course of an experiment and can affect the dependent variable(s). It is possible that previous facial muscle retraining received by all subjects facilitated the appearance of contamination effects in the data. Future studies could attempt to better monitor the influence of subjects' historical treatment. In doing so, however, another threat to internal validity, subject selection, would be compromised. With respect to concurrent historical factors, data were collected on a daily basis across the 13-week period, with the exception of weekends. It is doubtful, however, that changes in the dependent variables associated with concurrent historical factors would coincide precisely with the onset and termination of one of the two treatment conditions in this investigation. Maturation is probably not applicable in this study. Minimal physiological or psychological development is likely to occur across a 13-week period for the age range of the subjects who participated in this study. In contrast to the probably meagre influence of maturation factors in this study, however, a practice effect is a possible threat to internal validity. Data were collected frequently across the duration of the study, and an increase in "ramp function" accuracy and symmetry ratings was often observed in a target behavior either prior to the intervention of any treatment or when treatment was being applied to one behavior only; the writer referred to this effect earlier as a contamination effect. It is possible that this contamination effect was due to a practice effect instead. Although, if it were a practice effect, it was expressed inconsistently and at different times across subjects and behaviors. It would seem that a possible practice effect in single subject designs cannot be completely eliminated but should be addressed nonetheless.

Instrumentation refers to the effect that changes in an observational technique or measurement instrument might have on dependent measure(s). Instrumentation can become a threat to internal validity when humans are used as raters or judges of subject behavior or performance or when a mechanical device is utilized to measure behavior (Campbell & Stanley, 1963; Ottenbacher, 1986; Smith & Glass, 1987). In this study "instrumentation" is a possible threat to internal validity for several reasons including behavioral and technical phenomena. Among the behavioral issues were: (1) the judges were likely to have become more experienced and confident across the judging period; (2) the judges may have fatigued; (3) the judges may have become more relaxed or even more stringent in their judgements across the 5-hour rating task; (4) both measures of the dependent variable were somewhat subjective in nature; and (5) interjudge reliability measures for the photograph symmetry ratings were poor. Future investigations may lengthen the training period and apportion both the training period as well as the judging process across a longer period of time, possibly across a number of days, rather than during one day as was done in the present study. These changes would likely reduce the chances of the judge's becoming fatigued and judge rating/scoring consistency may increase. As well, less subjective dependent variables may reduce concerns regarding internal validity. The most influential technical threat was in the EMG biofeedback system associated with small but inevitable day-to-day variations in the subject-electrode interface and electrode placement. These variations made it impossible to utilize consistent training-line amplitudes or to increase the training target systematically when a performance criterion was achieved.

Statistical regression, subject selection and subject attrition are other factors which can compromise internal validity (Campbell & Stanley, 1963; Ottenbacher, 1986; Oyster, Hanten & Llorens, 1987; Smith & Glass, 1987). For this study, the issue of statistical regression probably was not a threat to internal validity. "Extreme" performances of facial gestures, corresponding to scores 1) either near the symmetrical or asymmetrical end of the symmetry rating scale or 2) either high or low with respect to "ramp function" accuracy may have been apparent when data collection was initiated and later may indeed have moved in the direction of an "average" score. It is likely, however, that scores collected across the duration of the study were associated with the treatment provided, because probe data collection was conducted frequently and across a relatively long period of time; "peaks" and "lows" in subject performance would eventually diminish and the resulting scores would be representative of a subject's true ability. Subject selection is seen as a significant threat to internal validity because all subjects were volunteers. Self-selection may therefore bias the results of the study towards characteristics shared by individuals that choose to voluntarily participate in a given study. Fortunately, subject attrition was not a threat to internal validity because all subjects had 100% attendance records.

Experimenter bias is included by Ottenbacher (1986) as a possible threat to internal validity. Experimenter bias refers to an investigator's influence on data gathered due to his/her expectations regarding subject performance. In the present study, not only did the principal investigator administer both treatment conditions to all subjects but she also was the only individual who rated all photographs and electromyograms for the purposes of primary data analysis. Additionally, during the B treatment phases the principal investigator stored some electromyograms (i.e., those she perceived as visibly symmetrical) associated with the production of "smile" and "snarl" gestures. Because mirror training was provided to the subjects in the absence of EMG feedback during this phase, any information about facial muscle EMG activity observed by the investigator would be considered another source of experimenter bias. Although the potential for experimenter bias was great, interjudge reliability was relatively high (65 - 75%) across the three judges for the "ramp function" accuracy judging task (Table 7, p. 70), suggesting that the external judges provided ratings similar to the investigator. Overall, however interjudge reliability was low (15 - 50%) across the three judges for the photograph symmetry rating task (Table 10, p. 72). Although this might suggest that the investigator's ratings were influenced by her expectations regarding subject performance, it is also likely that interjudge reliability for this task was low because of the difficulty of the task. That is, as mentioned on p. 79, the range of excursion did not change very much across time and hence it was difficult to obtain a consensus on the photograph symmetry ratings among the judges. Both for the "ramp function" rating task and the facial symmetry rating task interjudge reliability values were always higher between the primary investigator and one of the external judges than between the two external judges. These findings would suggest that the principal investigator's ratings were not necessarily biased, because ratings of photographs by one external judge were always in agreement more frequently with ratings of the principal investigator than with ratings of the other external judge (Table 10, p. 72). If, on the other hand, interjudge reliability had been greater between the two external judges than between one external judge and the investigator, experimenter bias would have been a greater threat to internal validity. Future investigations may be designed so that the clinician is not involved in judging or rating tasks and hence eliminate the threat of experimenter bias. This could be accomplished by recruiting a larger number of volunteers to act as judges than was available in the present study.

In summary, the five factors of primary concern with respect to internal validity were: (1) previous facial muscle retraining; (2) practice effects; (3) instrumentation; (4) subject selection; and (5) experimenter bias. A history of facial retraining may have facilitated the appearance of contamination effects in the data, but eliminating subjects with a history of related treatment would compromise another threat to internal validity, subject selection. Although suggestions to reduce the influence of a practice effect in future studies were provided, it is questionable as to whether this threat to internal validity can be completely eliminated in single subject designs which rely on collection of large amounts of repetitive behavioral data from the same subject across time. The principal investigator's concerns regarding instrumentation as a threat to internal validity should be noted and attempts should be made to minimize these factors in future investigations. Although subject selection can compromise internal validity, for ethical purposes it was necessary that subjects participate voluntarily in the study. Experimenter bias is a threat to internal validity but could be minimized in future investigations by designing studies such that the principal investigator is not involved in measurement of the dependent variable(s).

Threats to External Validity

External validity exists in single system studies when the results are representative of the effects that can be attained when the intervention is employed with different clients or in different settings (Ottenbacher, 1986). Generalizability of results from single system studies is accomplished through application of direct replication, systematic replication and clinical replication. Threats to external validity exist when replication procedures have not been employed. Thus, the issue of external validity of single system studies employs a different frame of reference than that used in group-comparison research (Ottenbacher, 1986).

Direct replication has been accomplished in the present investigation, because the original intervention application was replicated across three subjects. Systematic replication, according to Ottenbacher (1986), also is inherent in multiple-baseline designs and suggests that increased generalizability is one of the advantages of this design. Systematic replication compares the findings of a given treatment across other settings, clients, therapists and behaviors. Treatment effects in the present investigation were compared across two behaviors: "smile" and "snarl." It is important to note that although multiple-baseline designs may initiate the process of systematic replication, obtaining generalizability via this replication procedure is a long-term process; it may continue over an extended period of time before the generalizability of a treatment effect can be demonstrated. Clinical replication has not been achieved in this investigation. This form of replication is an advanced replication procedure and generally involves the application of related treatment procedures to a series of subjects with the same diagnostic syndrome (Hersen & Barlow, 1976).

A limitation of this investigation, lack of within-subject replication (p. 90), is also a threat to external validity. Efficacy of each of the treatment conditions has not been replicated across the same subject and therefore generalizability is compromised.

An additional limitation of this investigation, lack of treatment order or behavioral order counterbalancing (p. 87), also is a threat to external validity. Future studies may wish to utilize a larger subject pool, at least 12 subjects, to control for these order effects.

In summary, the results of this investigation showed an overall treatment difference compared to the baseline data for all subjects for the "smile" gesture and for three subjects for the "snarl," either when mirror training was compared to baseline data or when mirror training plus EMG feedback was compared to baseline data. Design and procedural limitations prevented the conclusion that one treatment condition was more potent than another, however. A number of those limitations have been discussed. With respect to the present study, baselines established for "ramp function" accuracy were generally variable. Baseline variability was exhibited less frequently in the symmetry rating data than in the "ramp function" data. Nonetheless, evaluations of patterns in the data based on visual comparison of the baseline and treatment phases are less than reliable because of baseline instability. Another limitation of the study were contamination effects. Contamination effects were exhibited by all subjects in the "ramp function" data and by two subjects in the symmetry data during the prolonged baseline phase of the "snarl" target gesture. During the prolonged maintenance phase for the "smile" gesture, one subject's data associated with "ramp function" accuracy and one subject's data associated with symmetry ratings displayed evidence of contamination. The primary concern when these conditions occur is that the results of intervention become ambiguous. Two additional limitations of this investigation that were discussed were that treatment order was not counterbalanced and that there was a risk of a behavior order effect on the results. The design of this study prevented the investigator's concluding whether similar trends in the data would exist had the subjects received training of each of the treatments for longer durations. Within-subject replication was not possible due to the time constraints of the investigation, and hence evidence of treatment effectiveness is limited because neither the "mirror-only" nor the "mirror-plus-EMG" treatment phases were repeatedly applied to the same subject across the same target behavior. Another limitation, ceiling effects, prevented an accurate indication of the extent of changes in facial symmetry across the duration of the study. Finally, interpretation of the results of the this study must be tempered by the recognition that several threats to both internal and external validity existed in the present investigation.

CONCLUSION

In conclusion, results from the present study suggest that improvement in both "ramp function" accuracy and symmetry ratings was exhibited for either the "smile," the "snarl" or both target behaviors across all subjects during the application of mirror training compared to baseline and during the application of "mirror-plus-EMG" treatment compared to mirror training. Hence, this investigation showed an overall treatment effect compared to the baseline data for all subjects. The conclusion that one treatment paradigm is more potent than another is obviated, however, by target behavior interdependence and ceiling effects exhibited in the data.

Results of the correlations that examined both the relationship between the accuracy of facial EMG "ramp functions" and the symmetry ratings of corresponding photographs, and the relationship between the amplitude ratios of bilateral facial electromyograms and the symmetry ratings of corresponding photographs revealed that the variables in question were only weakly, and sometimes inversely, related.

Interpretation of the findings must be tempered by the recognition that: (1) baseline data were rarely stable and therefore visual comparison of the data in the baseline and treatment phases are less than reliable; (2) the performance of one target behavior that was either in baseline or maintenance may have been contaminated by the treatment of the other target behavior; (3) ceiling effects prevented the data from reflecting an accurate indication of changes in facial symmetry; and (4) the number of subjects was small and the results of the investigation have not been replicated within each subject. Both threats to internal and external validity have been reviewed. Future studies attempting to examine the efficacy of mirror training and mirror training in conjunction with EMG feedback might utilize a changing performance criterion to allow for extended range of motion of target behaviors. Future investigations also may wish to utilize additional, less subjective, measures of the dependent variables to better quantify change in facial behavior across time.

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APPENDICES

APPENDIX A

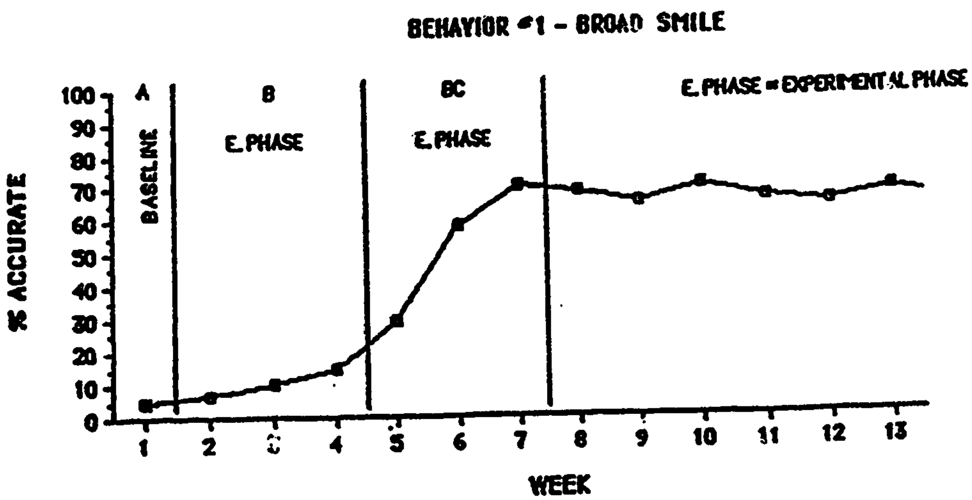
RESEARCH DESIGN AND HYPOTHETICAL MULTIPLE-BASELINE GRAPHS

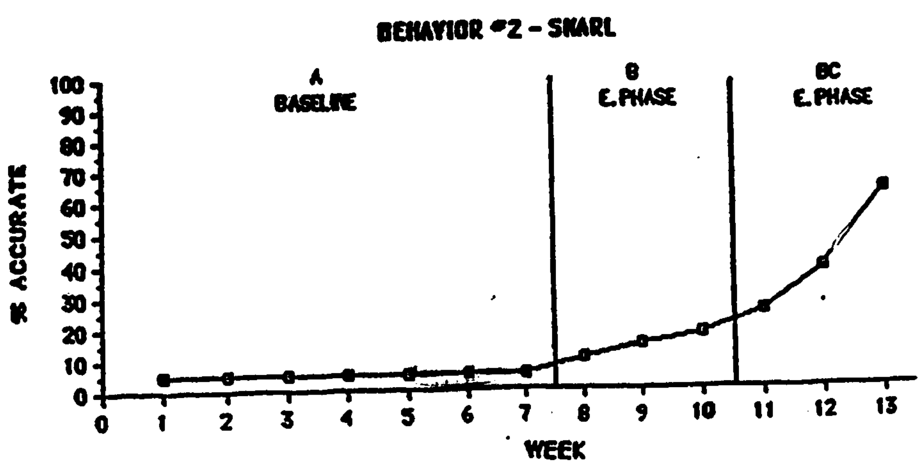
Research Design

Single-Subject Experimental Interaction-Multiple-Baseline Design

A-B1-BC1-B2-BC2

1 Week = 5 Sessions





APPENDIX B

FACIAL MUSCLE RETRAINING STUDY

Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
Department of Speech Pathology & Audiology
Faculty of Rehabilitation Medicine
University of Alberta, Edmonton
(403) 492-5990 or 492-7588 (Office)
(403) 481-9602 (Home, SPE)

PRELIMINARY INFORMATION LETTER FOR POTENTIAL PARTICIPANTS

Dear Sir/Madam;

I am currently enrolled as a graduate student in the Department of Speech Pathology and Audiology at the University of Alberta. In partial fulfillment of the requirements for the Master of Science degree, I am writing a thesis on an experiment investigating the relative effectiveness of two methods of facial muscle retraining. Professor Anne Rochet is my thesis supervisor. My thesis research will be supported by funds from the Medical Research Council of Canada and is an offshoot of Dr. Rochet's research program in facial muscle retraining.

I am hopeful that the Acoustic Neuroma Association of Canada (ANAC) will be the major recruitment source for the proposed investigation. Over the past year and a half, the ANAC has displayed sincere interest in, and generosity toward participation in Dr. Rochet's study of facial muscle retraining. Since January 1989 seven members of the ANAC have volunteered to participate in Dr.Rochet's project (funded by the Medical Research Council of Canada): Linda Gray (secretary/treasurer of ANAC), Madeleine Leipnitz (Alberta chapter contact), Joey Pickering, Mary Horak, and Thelma Barnett. Maggie Davidson and Wayne Erickson are presently enrolled in the project and receiving facial muscle retraining administered by the two research assistants on the grant, James Chou and myself. Indeed, it is my work as a research assistant on Dr. Rochet's grant that stimulated my interest in facial muscle retraining as the focus for my thesis.

Purpose: My thesis is designed to study changes in fine motor control of facial musculature associated with facial muscle retraining in individuals with unilateral (one side only) facial weakness, following facial nerve injury. I will be using two treatment methods: 1) specific facial exercise with visual feedback from a mirror; and 2) specific facial exercise with visual feedback not only from the mirror but also from a video monitor displaying the electrical activity of facial muscles (EMG).

Subjects: Four individuals will be trained across the duration of my thesis project. To be eligible, participants must present with unilateral facial weakness resulting from Bell's Palsy, acoustic neuroma, congenital paresis, or other conditions causing damage specifically to the facial nerve. As well, potential participants should be at least six months beyond the initial onset of the facial nerve injury, or at least nine months beyond a facial nerve graft or cranial nerve transfer surgery. [This recovery period helps to ensure that there are some regenerative motor units present that might respond to facial muscle retraining.] Participants will also be required to "pass" a screening procedure during which EMG signals from surface electrodes over muscles on both sides of the face will be observed while certain facial gestures are performed. This screening test will allow me to determine if there is measurable difference between the same muscle groups in the muscles on the weaker of the face versus the stronger side and if there is potential for improvement in the weaker side within the limits of my study.

Time frame: A substantial time commitment is required of the four participants. The study will run for 13 weeks, during which time each participant will be seen for five one-hour sessions weekly. I will make every effort to maintain this treatment schedule while minimizing the disruption of participants' personal agendas by providing opportunities for treatment sessions on weekdays, or weekday evenings or weekends, if necessary. Commencement of the project is dependent on the approval of my thesis proposal by my supervisory/ethical review committee. Pending approval of my proposal, the research project is tentatively scheduled to begin the week of 13 May 1991 and conclude the week of 5 August 1991.

The project will be conducted on the University of Alberta campus. There is no cost to participants associated with their receipt of facial muscle retraining during the research project, and a free parking place convenient to the treatment site will be made available to each participant for the duration of the project.

If you are interested in participating, or want more information about the project, please fill in the form below and send it to me, Sharon Evelyn, Department of Speech Pathology & Audiology, 400 Garneau Professional Centre, 11044-82 Avenue, Edmonton, Alberta, T6G-0T2. If you wish to telephone, I can be reached at (403) 492-0836/7588 (office) or (403) 481-9602 (home).

I am aware that by inquiring about this project, I am in no way obligated to participate in it.

Please send me more information about the facial muscle retraining

study________

Name:____

Address:____

City:________________ Province:______________

Postal Code:_______________

Phone: (Bus) ______________ (Res) ______________

Cause of facial weakness

(optional):____

Facial Muscle Retraining Study
Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
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APPENDIX C

FACIAL MUSCLE RETRAINING STUDY

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INFORMATION LETTER FOR POTENTIAL PARTICIPANTS

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Purpose: My thesis is designed to study changes in fine motor control of facial musculature associated with facial muscle retraining in individuals with unilateral (one side only) facial weakness, following facial nerve injury. I will be using two treatment methods: 1) specific facial exercise with visual feedback from a mirror; and 2) specific facial exercise with visual feedback not only from the mirror but also from a video monitor displaying the electrical activity of facial muscles (electromyography abbreviated as EMG) (see page two for an explanation of EMG feedback). Although both forms of treatment are presently being administered to individuals with facial weakness, as of yet, there is no empirical evidence indicating that EMG feedback enhances the effectiveness of mirror training when the two treatment methods are applied in a complementary relationship. The results of this study should expand the existing knowledge base for treatment of unilateral facial weakness, thereby increasing the effectiveness of designing and administering treatment programs for individuals in need of such rehabilitation.

Subjects Eligible to Participate: Four subjects will be trained across the duration of the research project. To be eligible to participate in the study, you must have unilateral (one side only) facial weakness due to an injury to the facial, or seventh cranial nerve. Potential subjects should be at least six months beyond the initial onset of the facial nerve injury. If you have had a cranial nerve transfer or facial nerve graft to restore facial muscle control, that surgery should have occurred at lease nine months ago. These limits have been chosen to allow time for you to have regenerated some motor units (fundamental components for producing muscle activity) on the weak side of your face that might respond to training. Potential participants will also be required to undergo a screening procedure during which EMG signals from surface electrodes over muscles on both sides of the face will be observed while certain facial gestures are performed. This screening test will allow me to determine if there is a measurable difference between the same muscles on the weaker side of the face versus the stronger side and if there is potential for improvement in the weaker side within the limits of my study.

Background Information about EMG Feedback: One aspect of training in this project will use EMG. EMG stands for ElectroMyoGraphy (electro = electrical, myo = muscle, graphy = display). An EMG machine is a computerized recording device used to measure the minute amounts of electrical activity present naturally in living muscle. The use of EMG is better understood following a brief explanation of how muscles and their nerves work. It is not necessary, however, to understand the complexities of EMG to participate in the study. Hence, the following three paragraphs should be considered optional but may be of interest to some potential participants.

The brain sends signals to the muscles in the form of small electrical impulses that are carried by the nerves. When an electrical signal is carried by a nerve into a muscle, the muscle will respond (contract) and generate its own electrical signal in the process. This nerve-muscle electrical communication is the basis of voluntary movement. The minute electrical voltage generated by the muscle can be picked up by electrodes in the form of needles placed in the muscle itself (intramuscular EMG), or by electrodes in the form of tiny discs placed on the skin overlying the muscle (surface EMG). Surface EMG will be the method of measuring electrical activity in the present investigation. Wires attached to the electrodes carry the tiny voltages associated with muscle activity from the muscle to an EMG machine which amplifies them and displays them in visible or audible form. The visible or audible displays of muscle activity are sometimes referred to as "EMG feedback." "EMG feedback," in this context, is information provided to an individual, via an audible or visible display, about muscle activity. In the present study, the visible form will be utilized. A line graph on a video display terminal, that is associated with the muscle activity will rise or fall as EMG activity increases or decreases.

The value of an EMG feedback display is particularly useful when muscular activity is faint, or weak, due to nerve damage. Sometimes when an injured nerve regenerates, its reconnections to muscles are too few to produce a visible movement, yet EMG electrodes may be able to detect a muscle response and display it. This gives a person information that a muscle is working, even before its response produces a movement visible to the naked eye.

It is important to remember that the EMG instrument itself does not stimulate the muscles; that is, it does not send electrical impulses into the body. Instead, it "senses" those that are present in a person's muscles. Hence, its use for facial muscle retraining in this research project involves no external stimulation. EMG electrodes will be used only to "pick-up" naturally-occurring electrical activity in facial muscles.

The Initial Screening Procedure: Prior to your participation in this research, you will be asked to submit to an EMG screening assessment of the facial muscle status on the strong and weak sides of your face. This assessment will take about an hour and will be performed at no cost to you. Electrodes will be applied to the surface of your skin (surface EMG) overlying at least two facial muscle locations while certain facial gestures are performed. This provides an opportunity to obtain the clearest possible picture of the status of specific muscles on both sides of your face. This screening test will allow me to determine if there are measurable differences between the same muscle groups on each side of your face and if there is potential for improvement on the weaker side within the limits of my study.

Procedures for the Retraining Sessions: Your participation in the study will span 13 weeks. Because this is a research project, it is vital that we follow standardized training schedules for all participants and collect as much information as possible, as carefully as possible. The training schedule is only mildly flexible but alternate treatment sessions can be arranged if you have to miss a session as the result of illness or a doctor's appointment. Information will be collected in the form of video-taped and 35mm photographic records, and facial muscle activity data via surface EMG. You will be asked to come in for these recordings and training five times per week for 1-hour sessions. You will also be asked to refrain from practicing the exercises you learn from me, on your own, while you are participating in the project. In addition, you will be asked to discontinue any other facial rehabilitation treatments in which you may be participating, just for the duration of the study.

The facial muscle retraining phases of the study involve systematic practice of facial movements using both sides of your face while looking in a mirror. In addition, some phases of the research will allow you to see a display of the EMG activity associated with those facial movements. This is referred to as "EMG feedback" and was alluded to previously on page two. The muscle activity will be picked up by small surface electrodes applied to the skin of your face over the muscles in training. The electrodes are non-invasive and should cause you no pain or physical discomfort. The EMG activity that you will see will be displayed on a computer video screen. This instrument is properly grounded so you are in no danger of electrical shock.

Skin Preparation for Surface EMG: Because the connection between the electrode and your skin must be as good as possible, the skin surface where electrodes are attached will need to be cleaned with a "skin prep" solution and slightly abraded each time the electrodes are applied. Furthermore, because the following things tend to leave residues on the skin that interfere with good electrode connections, you may be asked to eliminate them from your daily facial skin-care routine for the duration of the experiment: deodorant soaps, facial creams, ointments or oils of any sort and pancake makeup. Thick facial hair also interferes with good electrode placement and skin interface. Hence, if you are a man with a beard, you may be asked to shave it for the duration of the experiment.

Videotaping and Photography: Video-taped recordings of you, performing various facial gestures, and 35mm photographs will be collected throughout the research investigation. The field of view will include your head, neck and shoulders, and you will be draped with a cloth over the neckline of your clothes to standardize the color and context of the picture from recording to recording. If you consent to take part in this facial muscle retraining project it is assumed that you also consent to these video-taping and photographic procedures. The video-taped and 35mm photographic records are primarily for the purposes of reliable electrode placement and data analysis. To insure confidentiality of your records the principal investigator will secure them in a locked file cabinet accessible only to the principal investigator and her supervisor. The video recordings and photographs will be viewed only by thesis committee members and clinicians involved in the project expressly for the purpose of assessing the records. A coding system will be developed and implemented to ensure that your anonymity will be maintained during the proposed investigation with respect to all data forms.

Other Considerations: The project will be conducted on the University of Alberta campus, and a free parking place convenient to the treatment site will be made available to you for the duration of the project. While there is no direct cost to you for the facial muscle retraining you receive as a participant in this research, the project does require a substantial time commitment on your part. Prior to your participation in any training, you will be scheduled for a screening assessment (see page 1) and a video-taped interview with me during which I will review the historical details of your facial weakness with you and provide you with an orientation to the training project.

If you choose to take part in this research I will also ask your permission to review the medical records associated with the diagnosis and management of your facial nerve disorder. Be assured, however, that the execution of this research and the conduct of its personnel are governed by the University of Alberta's policy related to ethics in human research, and your welfare and dignity will therefore be protected during the course of the project. In addition, any professional or academic presentations or publications derived from the study will maintain your anonymity.

Caveats: Your eligibility for this study is determined by the specific questions that the investigation is addressing. Therefore, if the "screening" results indicate that you are not eligible for the study, this in no way indicates that you are not a suitable candidate for rehabilitation of your facial paralysis.

There are no known liabilities associated with your participation in the proposed investigation. You may feel a slight stinging sensation either when the "skin prep" solution is being applied or when the surface electrodes are peeled off the skin, but both types of potential irritation usually are mild and temporary. Because the proposed treatment is based on other research and/or techniques found clinically useful it is hoped that you will experience some improvement in the specific aspects of facial muscle control on which training will be focused. It is not possible for me to guarantee that improvement, however.

Further inquiry about this project in no way obligates you to participate in it. You are free to ask questions or present concerns with regards to the research at any time. If you have questions or concerns about the study or the conditions of participation please feel free to contact me, Sharon Evelyn, Department of Speech Pathology & Audiology, 400 Garneau Professional Centre, 11044-82 Avenue, Edmonton, Alberta, T6G-0T2. If you wish to telephone, I can be reached at (403) 492-0836/7588 (office) or (403) 439-3594 (home).

Thank-you for your consideration of this information.

Facial Muscle Retraining Study
Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
Department of Speech Pathology & Audiology
Faculty of Rehabilitation Medicine
University of Alberta, Edmonton
(403) 439-3594 (Home, SPE)
(403) 492-5990 or 492-7588 (Office)

APPENDIX D

FACIAL MUSCLE RETRAINING STUDY

Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
Department of Speech Pathology & Audiology
Faculty of Rehabilitation Medicine
University of Alberta, Edmonton
(403) 492-5990 or 492-7588 (Office)
(403) 481-9602 (Home, SPE)

SUBJECT'S CONSENT FORM

Name:______________________________________

I have read the information document regarding the facial muscle retraining study to be conducted by Sharon Evelyn. I believe I understand its contents, the procedures, the purpose and the time commitment required. I have felt free to ask questions about the project, and they have been answered to my satisfaction.

I understand that:

1. An initial video-taped personal interview will be conducted. At that time I will be asked questions concerning the diagnosis and treatment of my unilateral facial paralysis/paresis.

2) Following my interview, a video-taped screening procedure will be conducted which I must "pass" to be eligible to participate in the study. I understand that surface electrodes will be applied to the skin on my face overlying the muscles of interest during this procedure.

3) If I am not eligible for the study, I understand that it does not necessarily reflect my potential for facial muscle retraining, but rather reflects the specific design limitations of the research project to accommodate my particular facial muscle status.

4) The facial muscle retraining project spans 13 weeks during which I will visit the project's research office on the University of Alberta campus five times per week for 1-hour sessions. My participation throughout the 13 weeks will be documented in video-taped and 35mm photographic records, and my facial muscle activity will be recorded via surface EMG. I understand that this form of EMG uses non-invasive, surface electrodes, and that no external stimulation of my nerves or muscles is involved in the training.

5) I am aware that the principal investigator is unable to guarantee facial muscle control improvement over the course of the investigation.

6) There are no known liabilities associated with my participation in the proposed investigation. I may feel a slight stinging sensation either when the "skin prep" solution is being applied to my face or when the surface electrodes are peeled off my skin.

7) Information derived from my participation in this research will expand the existing knowledge base for treatment of unilateral facial weakness, thereby, increasing the effectiveness of designing and administering treatment programs for individuals in need of such rehabilitation.

8) The execution of this research and the conduct of its personnel are governed by the University of Alberta's policy related to ethics in human research. In accordance with those regulations, my welfare and dignity will be protected during the course of this project, and my anonymity will be guaranteed in any professional or academic publications or presentations derived from it. The video-taped, photographic and computer data associated with my participation will be coded and kept in a secure area accessible only to the principal investigator and her supervisor. The video recordings and slides will be viewed only by thesis committee members and clinicians involved in the project expressly for the purpose of assessing the photographic records.

I will attempt to stay with this project for the 13-week duration of my training. Nevertheless, I am aware that I am free to withdraw from this study at any time without consequence.

By signing below, I acknowledge that I have been adequately informed about the purpose and procedures of this project and the extent of my obligations and privileges as a participant in it. My signature confirms my voluntary consent to participate and acknowledges my receipt of a copy of this consent form and an information letter.

Subject's signature　　　　Date

Subject's printed name　　　　Witness

Principal Investigator's signature

APPENDIX E

FACIAL MUSCLE RETRAINING STUDY

Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
Department of Speech Pathology & Audiology
Faculty of Rehabilitation Medicine
University of Alberta, Edmonton
(403) 492-5990 or 492-7588 (Office)
(403) 481-9602 (Home, SPE)

CASE HISTORY QUESTIONNAIRE

Name:______________________ Birth date: (D/M/Y) __/__/__

Address:______________________ Telephone: (home)_______
______________________ (work)_______

Gender: female__ Male__

Hand preference for writing: right__left__

WORK AND FAMILY

Occupation(s) If you are retired or not working at the present time, please mention your former occupation:
____

Employer(s)__________________________________

Professional or personal factors (e.g., job or family responsibilities) that must be considered if you choose to participate in this project:
____
____

MEDICAL HISTORY

Site of facial weakness: left side______ right side______

Name of current attending physician re: your facial palsy:___________

May we contact him/her for more information, if necessary ?
no______ yes_____

If yes, please supply physician's address and phone:__________________
____
____

Cause of facial weakness: Please answer the questions that pertain to the cause of your facial weakness.

____**TUMOR** [Please provide details about tumor type, treatment and subsequent repair surgery.]

Type: Acoustic neuroma____
meningioma____
other?______________________________

Did you have radiation treatment for the tumor? no____ yes____
If yes, when?________________How much (in rads)?__________

Did you have surgery to remove the tumor? no____yes____Date:_______

Type of surgical procedure (if known):
translabyrinthine approach_____
posterior fossa approach______
other?______________________________

May we have your permission to review the records, if necessary?no__yes_

If yes, please supply name(s) and address of surgeon(s):

____
____
____

Have you had surgery to reinnervate your face? no___yes___Date:_____
Type of procedure (if known):

_____nerve transfer:
twelve-to-seven _____
eleven-to-seven _____
other?______________________________

_____cross-facial nerve graft:
sites of graft:brow_____upper lip_____other___________

_____facial muscle sling:
source of sling:masseter_____temporalis____other?_____

May we have your permission to review the records, if necessary?
no____yes____

If yes, please supply name(s) and address of surgeon(s):

____
____
____
____

Causes of facial weakness, continued...

____**BELL'S PALSY** Date of onset:______________________

Duration of acute stage:______________________________________

Did you have drug treatment? no_____ yes_____

If yes, with what drug and for how long?__________________________

_____**TRAUMA**

Type: skull fracture_____ ear surgery_____

facial injury______ facial surgery_____

other?____

Treatment?____

_____**INFECTION** Date:______________________

Type: Ramsay-Hunt Syndrome (Herpes zoster)_____

Otitis media (middle ear)_____

other?____

Treatment?____

_____**ALTERED METABOLIC STATE** Date:____________________

Type: pregnancy_____

diabetes_____

high blood pressure_____

other?____

_____**OTHER CAUSES?** Date:______________________

Type (please describe):____

____

____

____

THERAPY Please answer the questions that pertain to any treatment you have received for your facial weakness.

_____**Electrostimulation therapy** Date started____Date stopped____

Therapist:________________Location:_______________________________

Reason for therapy:____

Results:____

_____**Speech therapy** Date started_________ Date stopped______

Therapist:________________Location:_______________________________

Reason for therapy:____

Results:____

Types of therapy procedures used:_________________________________

____

If EMG feedback was used, was it audible? (tones/clicks)__Visible_

Results:____

_____**Occupational therapy** Date started_________ Date stopped_____

Therapist:________________Location:_______________________________

Reason for therapy:____

Results:____

Types of therapy procedures used:_________________________________

If EMG feedback was used, was it audible? (tones/clicks)__Visible_

Results:____

_____**Physical therapy** Date started_________ Date stopped______

Therapist:________________Location:_______________________________

Reason for therapy:____

Results:____

Types of therapy procedures used:_________________________________

If EMG feedback was used, was it audible? (tones/clicks)__Visible_

Results:____

CURRENT STATUS: Please answer candidly the following questions about the current status of your face, eye and ear on the side affected by your facial nerve injury.

How would you classify your facial weakness? (circle a number)

1 (mild) 2 3 (moderate) 4 5 (severe) 6 7 (very severe) 8

Please rate the **resting muscle tone** and **function** on the WEAK side of your face:

Resting Tone: (compared to strong side)			Performance of weak side of face during the following gestures (compared to strong)		
Cheek:	good_____	poor____	Eyebrow elevation:	good__	poor__
Corner of mouth:	good_____	poor____	Eye closure:	good__	poor__
Chin:	good_____	poor____	Smile:	good__	poor__
Neck:	good_____	poor____	Lip pucker:	good__	poor__
			Snarl:	good__	poor__

Do you have any **synkinesis** on the weak side of your face? (i.e., do you have any more movement than you intend when you try to talk or to control certain parts of your face on the weak side? If yes, when and where?) ______________________________

____

Do you have any **twitching** on the weak side of your face? (If yes, when and where?) ______________________________

____

Do you have any **pain or discomfort** on the weak side of your face? (If yes, describe?) ______________________________

Do you have any problems with **drooling** on the weak side of your mouth? (If yes, when?) ______________________________

Do you have problems with **fatigue**? (If yes, where, and on what tasks?) ______________________________

Do you have any **speech** problems associated with you facial weakness? (If yes, describe?) ______________________________

Do you have any **loss of sensation** on the weak side of your face? (If yes, please explain?) ______________________________

Do you have any other complaints about the behavior of the strong side of your face since acquiring facial weakness on the other side? (If yes, please explain?) ______________________________

____

What is the status of your eye on the weak side of your face?

Need artificial tears______

Have tarsorrhaphy______

Other?____

What is the status of your HEARING on the side of your facial weakness?

good:____

hearing loss:_____ mild_____ moderate_____ severe_____

hearing non-functional_____

Do you have any tinnitis? (ringing or roaring noises in the ear)no__yes_

ADDITIONAL INFORMATION:

If there is additional information that you feel will help us understand your problem better, please provide it here____________________________
____
____
____
____

Signature:______________________________ Date:______________________

Thank-you for completing this form. When you come in for your initial interview, we would be grateful if you would be prepared to discuss with us further these or any other aspects of your diagnosis, recovery from rehabilitative surgery, and treatments that you think may be pertinent to your participation in this research.

APPENDIX F

DESCRIPTION OF NEUROEDUCATOR

Source: Therapeutic Technologies Incorporated (1988)

(1) EMG processor: will record and process the EMG signals from one to four muscle groups simultaneously. The proposed investigation will require EMG signals to be monitored from two muscle groups. However, only one muscle group (bilaterally) will be recorded and processed at one time.

(2) Keyboard: allows the operator (principal investigator acting as clinician) to access the operator display.

(3) Operator display: permits the clinician to enter programming data into the EMG processor. This includes channel selection, or adjustment of either the sweep speed (10 to 200 second range) or the amplitude (10 to 800 microVolt range) of the EMG signal as displayed on the patient video monitor. The operator display will be arranged so that it can be viewed only by the clinician.

(4) Patient display: is slightly larger than the operator display and will be utilized by both the subject and the researcher during different phases of the investigation. It is the sole means of providing on-line feedback with regard to the visual analog of the surface EMG signal.

(5) Color, screen-dump printer: is utilized to provide hard copy records of the graphs displayed on the patient display or numerical data associated with the graphs.

(6) Patient cables: relay EMG signals from the patient to the EMG processor and divides into four cable ends which are numbered to correspond with the four channels available to monitor EMG signal feedback.

(7) Leadwires: active and reference (ground), consist of snap connectors on one end (to be fastened to the electrodes) and pin connectors on the other end, which will be plugged into an appropriate cable end.

(8) Isolation Transformer: This component supplies power to the other components of the NeuroEducator. Because the transformer unit is connected to a three-wire ground outlet, it delivers equivalent voltages to each individual component of the NeuroEducator. Hence, electrical isolation is provided to the entire unit and prevents occurrences of electrical shock to the subject. The isolation transformer meets the criteria established by the Canadian Standards Association.

APPENDIX G

FACIAL MUSCLE SKETCH

TARGET MUSCLES

Zygomatic muscle group
Levator muscle group

Electrodes were placed bilaterally superficial to the Zygomatic muscle group associated with lip spreading during production of a "broad smile."

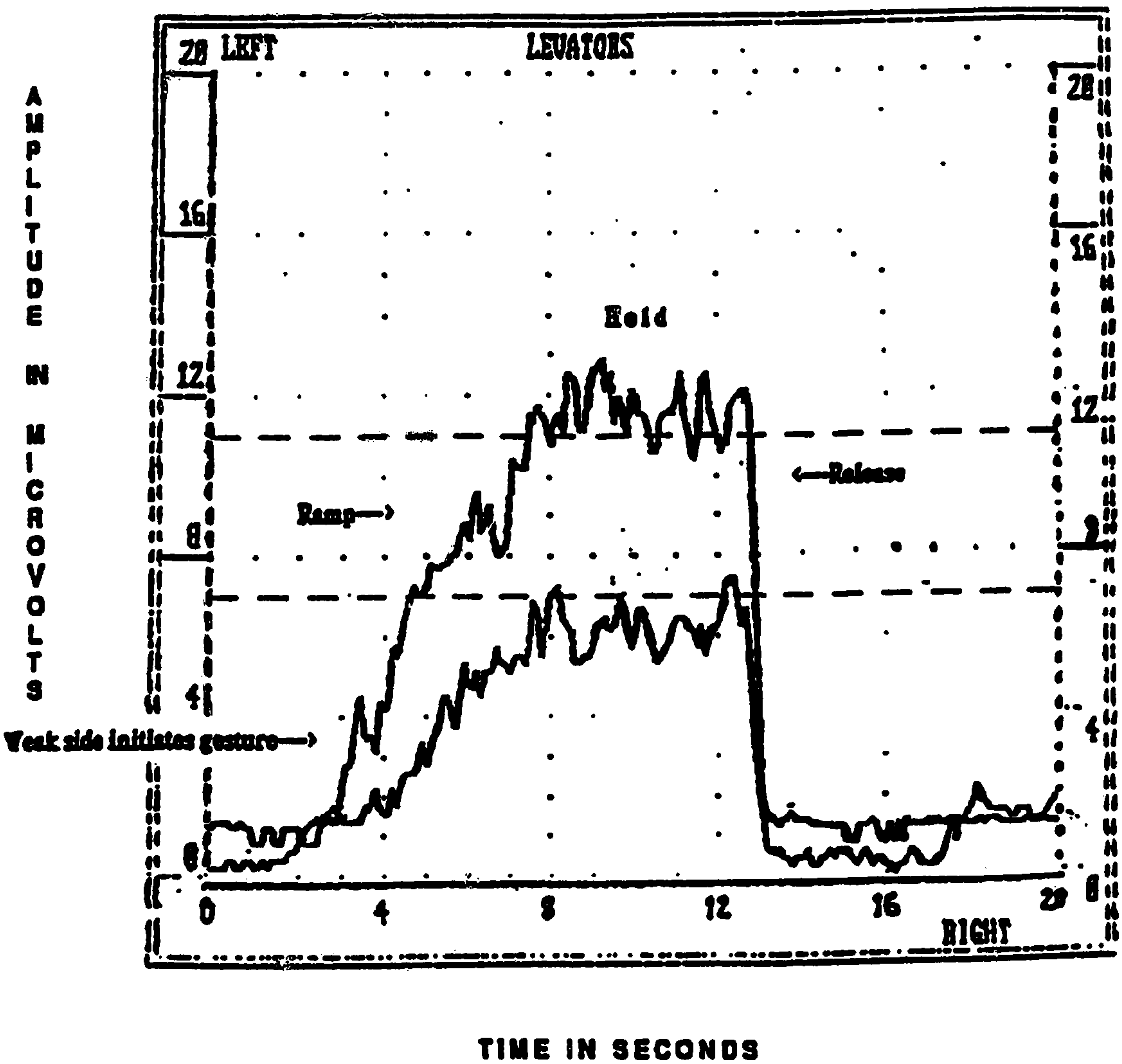
Electrodes were placed bilaterally superfical to the Levator muscle group associated with lifting the upper lip during production of a "snarl."

– ground sites at hairline over zygoma

APPENDIX H

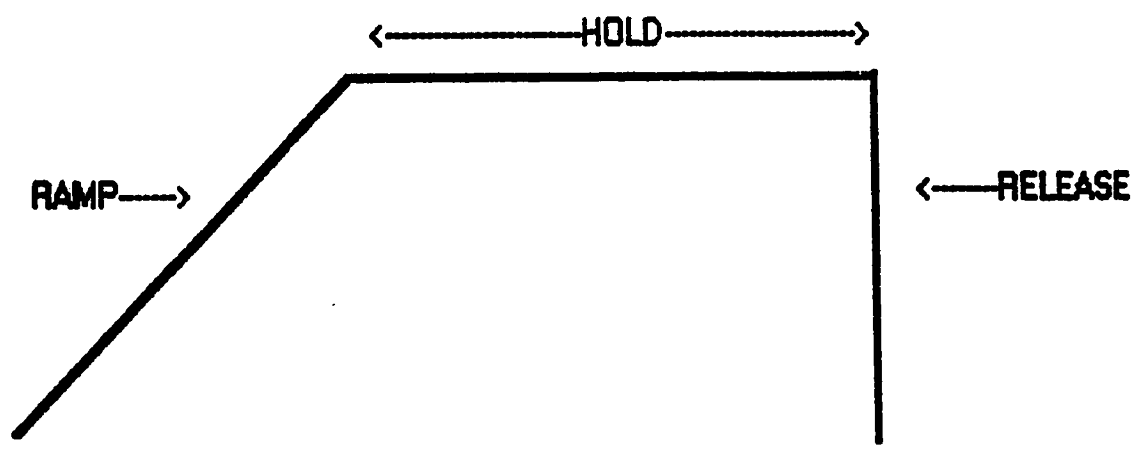
"RAMP FUNCTION" MODEL

Adapted from: Balliet, R. (1989)



APPENDIX I

"RAMP FUNCTION" SCHEMATIC



APPENDIX J

BALANCE NORMALIZATION FIGURE

APPENDIX K

ELECTROMYOGRAM CRITERIA

Please cover components of the "ramp function" that are not being assessed at a given point in time so that they do not bias your assessment of the "target" component.

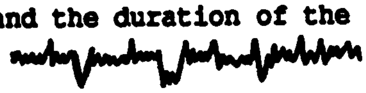
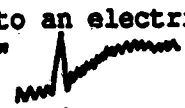
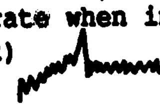
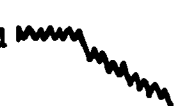
INITIATION:

-either the signal representing the weak side of the subject's face should initiate the production of the target gesture or the signals representing the weak and strong sides should increase in amplitude simultaneously
-fluctuations will be apparent during the "resting" portion of the "ramp function"
-ignore twitches immediately preceding the initiation
-gesture has been initiated when a signal continues to move in an upward direction and does not dip back down to the "resting level"
-if subject corrects an overshoot they should receive credit 
-use a ruler for determining which side initiated the gesture

RAMP:

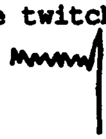
-should be continuous and flowing up to the point the "hold" begins
-must be on an angle (i.e., EMG signal should not increase in a vertical direction)
-ignore blink twitches
-can have some fluctuations as long as the direction and angle of the ramp is consistent
-degree of slope will vary from  to  (again, want consistency within each graph)
-in some instances you will give either the ramp credit or the hold
-if subject corrects an overshoot they should receive credit

HOLD:

-should be only one "hold" per function
-"hold" can have dips and peaks as long as the signal can be bisected horizontally and the duration of the "dips" and "peaks" is no greater than 1 second 
-"hold" can be on a slight angle , , , not  or 
-"hold" should be at least two seconds in duration
-ignore large twitches (possibly due to an electrical short) at the beginning or end of a "ramp function" 
-"hold" may appear to be inaccurate when in fact an inaccurate "ramp" is the problem (i.e., an overshoot) 
-do not mistake a slow release for a poor hold 

ELECTROMYOGRAM CRITERIA - CONTINUED

RELEASE:

-can have a <u>slight</u> angle on the way down to the resting level (1 second max.)
-initial resting level indicates whether or not a complete release is present/absent (i.e., does the release drop completely down to the level of the initial resting level - use a ruler for accuracy)
-signal should drop down to resting level within 1 1/2 seconds
-do not mistake a slow release for a poor "hold"
-ignore large twitches at the end of a "hold" or initiation of a "release" 

APPENDIX L-1

PHOTOGRAPH SYMMETRY CRITERIA (SUBJECT E.H.)

--LEFT SIDED PARESIS--

SNARL:

3 - SYMMETRICAL
-bottom lip is relatively straight (horizontal)
-appears visually symmetrical
-equal amount of excursion on both sides of the face
-equal distance between upper and lower lip

2 - MILDLY ASYMMETRICAL
-bottom lip nearing symmetry
-less lifting on left side as compared to right
-some apparent lifting on left side
-less cheek activity on left side of the face than seen in moderately asymmetrical gesture
-very close to appearing visually symmetrical

1- MODERATELY ASYMMETRICAL - one or a combination of the following may be apparent
-right levator apparently high relative to left levator
-visible pulling from left corner in an attempt to lift upper lip (incorrect)
-right side not too much higher than weak, but NO lift on the left side
-strong outward pulling from corner
-minimal lifting on left side
-definite curve in upper lip on the right side of subject's face
-upper teeth **not** showing on right side
-visible attempt to limit amount of excursion on right side of face
-may be no lift present on left side of face

0 - SEVERELY ASYMMETRICAL
-upper teeth **showing** on right side
-right side noticeably higher than left side
-minimal to no upward movement on left side of face
-bottom lip slanted
-sharp pulling from the corner of the mouth on the left (weak) side of the face
-upper lip on the right side of the subject's face is **much** higher than the left side
-no apparent attempt to produce symmetrical gesture
-nostril on the right side of the subject's face is higher than the nostril on the left side
-cheek involvement apparent on the left side of the subject's face (appears as though subject is attempting to smirk and snarl simultaneously)

(SUBJECT E.H. - CONTINUED)

--LEFT SIDED PARSIS--

SMILE - must attempt to visualize depth - subject's smile goes back towards her ears moreso than up towards her eyes

3 - SYMMETRICAL

-bottom lip should be symmetrically visible
-shape of the upper and lower lips should be symmetrical
-visibly equivalent excursion bilaterally
-line between upper and lower lip is relatively horizontal

2 - MILDLY ASYMMETRICAL

-both sides of subject's face apparently involved in production of the gesture
-not quite equivalent lifting bilaterally
-horizontal line between upper and lower lip is apparent
-fold at corner of mouth on the left side of subject's face is apparent
-bottom lip is visible

1 - MODERATELY ASYMMETRICAL

-right side apparently over involved
-bottom lip barely visible
-apparently more activity on right than left side of subject's face
-lips are compressed (appear tense)

0 - SEVERELY ASYMMETRICAL

-right side of face presents with much more involvement than left side
-left side is minimally involved but is being pulled downward rather than upward
-right side of the mouth is curling up noticeably more than the left side
-left side of the mouth is curled down toward the chin

APPENDIX L-2

PHOTOGRAPH SYMMETRY CRITERIA (SUBJECT M.L.)

--RIGHT SIDED PARESIS--

SNARL

3 - SYMMETRICAL

-absence of tightness in lip (OOS) area on right side of subject's face
-equal distance between lips on both sides of her face
-absence of apparent cheek activity (i.e., no pulling from the corner of her mouth on the right side of her face)

2 - MILDLY ASYMMETRICAL

-very close to appearing visually symmetrical
-slight touching of bottom and top lip on one side of her face therefore, asymmetrical distance between lips on both sides of her face
-right and left sides of her face have equal amounts of excursion (i.e., lifting of the upper lip)
-slight pulling of the cheek muscles on the right side of her face - corner of lips appear more pointed on the right side of her face than on the left

1- MODERATELY ASYMMETRICAL

-increased touching of the top and bottom lips on the right side of her face relative to the left side, moreso than that apparent in a mildly asymmetrical gesture
-right and left sides of her upper lip do not present with equal amounts of excursion (generally the upper lip on the left side of her face is lifted higher than the upper lip on the right side of her face)
-apparent extensive cheek involvement (very noticeable pulling of the corner of her mouth back towards the lower part of her ear)

0 - SEVERELY ASYMMETRICAL

-nasolabial fold much more apparent on the right side of her face than on the left
-cheek involvement very apparent (appears as though subject is attempting to smirk and snarl simultaneously)

(SUBJECT M.L. - CONTINUED)

--RIGHT SIDED PARSIS--

SMILE

3 - SYMMETRICAL

-gestures appears visually symmetrical at first glance
-lack of tightness in the lip area (i.e., lips do not appear compressed)

2 - MILDLY ASYMMETRICAL

-slightly unequal excursion bilaterally
-the right corner of the mouth is horizontal or pulled slightly downward (lack of upward curl as is apparent on the left side of her face)
-minimal tightness in the lip area
-right corner of the mouth is slightly lower than the left corner of the mouth

1 - MODERATELY ASYMMETRICAL

-similar to "2" but greater visual difference between the right and left sides of subject's face
-an apparent lack of upward curl not only on the right side of the subject's face but also on the left side

0 - SEVERELY ASYMMETRICAL

-right corner of mouth is much lower than the left corner of the subject's mouth
-the right corner of the mouth is apparently pulled downward

APPENDIX L-3

PHOTOGRAPH SYMMETRY CRITERIA (SUBJECT L.G.)

--RIGHT SIDED PARESIS--

SNARL

3 - SYMMETRICAL
-equal lifting of the upper lip bilaterally
-perioral region appears relaxed - absence of tightness in lip (OOS) area on right side
-equal distance between lips on both sides of her face
-both the upper and lower lips appear visually symmetrical

2 - MILDLY ASYMMETRICAL
-very close to appearing visually symmetrical
-minimal asymmetry related to varying amounts of excursion on the right and left sides of subject's face
-bottom lip might be slightly asymmetrical

1- MODERATELY ASYMMETRICAL
-appears to be a visible attempt to produce symmetrical gesture
-left (strong) side of face has a higher lift than the right (weak) side
-visible chin activity (i.e., dimpling)
-bottom lip is relatively horizontal

0 - SEVERELY ASYMMETRICAL
-upper lip on the left side of the subject's face is **much** higher than the right side
-no apparent attempt to produce symmetrical gesture
-bottom lip may be slightly tilted
-nostril on the left side of the subject's face is higher than the nostril on the right side
-cheek involvement apparent on the right side of the subject's face (appears as though subject is attempting to smirk and snarl simultaneously)

(SUBJECT L.G. - CONTINUED)

--RIGHT SIDED PARSIS--

SMILE

3 - SYMMETRICAL
-equal excursion bilaterally
-line running between upper and lower lip is horizontal

2 - MILDLY ASYMMETRICAL
-visible attempt to balance both sides of the face (lip area)
-generally no lifting on either side (corners of the mouth)
-line running between upper and lower lip is fairly horizontal
-relatively equal amounts of vermillion are visible

1 - MODERATELY ASYMMETRICAL
-noticeable attempt to balance both sides of face
-downward pulling still apparent on right side
-line running between upper and lower lip is somewhat slanted
-too much lifting on left side of the subject's face, some lifting, however, is apparent on the right side
-asymmetrical vermillion

0 - SEVERELY ASYMMETRICAL
-left side curling up noticeably more than the right side
-right side of the mouth is curled down toward the chin

APPENDIX L-4

PHOTOGRAPH SYMMETRY CRITERIA (SUBJECT H.G.)

--LEFT SIDED PARESIS--

SNARL

3 - SYMMETRICAL
-apparent equal lifting of the upper lip bilaterally
-bottom lip is horizontal and even
-space between upper and lower lips won't be equal because the right side shows more vermillion than the left

2 - MILDLY ASYMMETRICAL
-nearing symmetry
-bottom lip is horizontal
-no pulling of corner (i.e., cheek involvement)

1- MODERATELY ASYMMETRICAL
-minimal but apparent attempt to lift the left side
-strong side too high relative to weak side
-one side of lip is pulling down towards chin
-apparent attempt to reduce amount of excursion of the strong (right) side - pulling from corner is apparent

0 - SEVERELY ASYMMETRICAL
-strong side up too high relative to weak side
-no activity on weak side
-strong pulling from the corner
-no lifting on either side - only pulling down of bottom lip toward chin

SMILE

3 - SYMMETRICAL
-equal excursion bilaterally
-right and left side appear symmetrical

2 - MILDLY ASYMMETRICAL
-lips appear to be pressed tightly together
-strong side not quite as high as the weak side

1 - MODERATELY ASYMMETRICAL
-strong side way too far relative to weak (left) side
-lips may be compressed

0 - SEVERELY ASYMMETRICAL
-strong side exhibits much more involvement than weak side

APPENDIX M

FACIAL MUSCLE RETRAINING STUDY

Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
Department of Speech Pathology & Audiology
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EXTERNAL JUDGE INFORMATION DOCUMENT AND CONSENT FORM

Appearance of Facial Muscle EMG Signal Reliability

I am currently enrolled as a graduate student in the Department of Speech Pathology and Audiology at the University of Alberta. In partial fulfillment of the requirements for the Master of Science degree, I am writing a thesis on an experiment investigating the relative effectiveness of two methods of facial muscle retraining. Professor Anne Rochet is my thesis supervisor. My thesis research is supported by funds from the Medical Research Council of Canada and is an offshoot of Dr. Rochet's research program in facial muscle retraining.

Purpose: My thesis was designed to study changes in fine motor control of facial musculature associated with facial muscle retraining in individuals with unilateral (one side only) facial weakness, following facial nerve injury.

Variables: One independent variable, facial muscle treatment, with two levels, mirror treatment ("mirror only") and mirror treatment in conjunction with information about facial muscle electromyographic (EMG) signal activity ("mirror plus EMG") was utilized. The two dependent variables in this investigation were performance of a "smile" and performance of a "snarl." Two subjective criteria were utilized to analyze each dependent variable. One criterion was the perception of facial symmetry apparent in photographs collected across the duration of the study and rated on a scale ranging from 0 to 3. The second criterion was the appearance of hard copies of the facial muscle EMG signal electromyograms associated with subjects' probe performances.

Reliability Procedures: You are being asked to participate in a visual analysis of 176, coded electromyograms displaying bilateral facial muscle activity patterns ("ramp functions") that will be presented to you in random order. The electromyograms will be scored according to a protocol based on eight criteria. The entire judging process will take approximately 5 hours, excluding three 20-minute breaks. The breaks will be scheduled beforehand and will provide you with an opportunity to relax and prepare for the next group of electromyograms.

Training: One session, approximately 2 hours in duration, will be devoted to training in preparation for the electromyogram assessment task. During the first 1 1/2 hours of the session the principal investigator will describe the parameters to be studied (i.e., initiation of target muscle activity, the slope and hold of the "ramp function," and the release of facial muscle activity associated with one of the two target gestures). In addition, the clinician and the principal investigator will assess the specified parameter in its graphic form as it will appear during the data analysis and reliability stages of the investigation. The remaining 1/2 hour will involve independent analyses of electromyograms by you, the judge, and the principal investigator. This training will terminate when 95% reliability has been established between the judge and the principal investigator for assessment of selected EMG records.

Other Considerations: Electromyogram assessment will be conducted on the University of Alberta campus, room 2-20, Corbett Hall. The assessment task must take place in the research office, because the electromyograms must remain secure there. Be assured that the execution of this research project and the conduct of its personnel are governed by the University of Alberta's policy related to ethics in human research. Any professional or academic presentations or publications derived from the study will maintain your anonymity. The data associated with your participation in this project will be coded and kept in a secure area accessible only to the principal investigator and her thesis committee members.

You are free to ask questions or present concerns to the principal investigator with regards to the research. You are free to withdraw from this project at any time without consequence.

By signing below, you acknowledge that you have been adequately informed about the purpose and procedures of the endeavor and the extent of your obligations as a participant in it. Your signature confirms your voluntary consent to participate and acknowledges your receipt of a copy of this information document and consent form.

____________________ Subject's signature	________________ Date
____________________ Subject's printed name	____________________ Witness
	____________________ Principal Investigator's signature

APPENDIX N

FACIAL MUSCLE RETRAINING STUDY

Sharon P. Evelyn, B.Sc., Principal Investigator
Anne Putnam Rochet, Ph.D., Thesis Advisor
Department of Speech Pathology & Audiology
Faculty of Rehabilitation Medicine
University of Alberta, Edmonton
(403) 492-5990 (Office) or 439-3594 (Home, SPE)

EXTERNAL JUDGE INFORMATION DOCUMENT AND CONSENT FORM

Perception of Facial Symmetry Reliability

I am currently enrolled as a graduate student in the Department of Speech Pathology and Audiology at the University of Alberta. In partial fulfillment of the requirements for the Master of Science degree, I am writing a thesis on an experiment investigating the relative effectiveness of two methods of facial muscle retraining. Professor Anne Rochet is my thesis supervisor. My thesis research is supported by funds from the Medical Research Council of Canada and is an offshoot of Dr. Rochet's research program in facial muscle retraining.

Purpose: My thesis was designed to study changes in fine motor control of facial musculature associated with facial muscle retraining in individuals with unilateral (one side only) facial weakness, following facial nerve injury.

Variables: One independent variable, facial muscle treatment, with two levels, mirror treatment ("mirror only") and mirror treatment in conjunction with information about facial muscle electromyographic (EMG) signal activity ("mirror plus EMG") was utilized. The two dependent variables in this investigation were performance of a "smile" and performance of a "snarl." Two subjective criteria were utilized to analyze each dependent variable. One criterion was the perception of facial symmetry apparent in photographs collected across the duration of the study and rated on a scale ranging from 0 to 3. The second criterion was the appearance of hard copies of the facial muscle EMG signal electromyograms associated with subjects' probe performances.

Reliability Procedures: You are being asked to rate the symmetry of 176, coded, 5 x 7 color photographs of "smile" and "snarl" facial gestures that will be presented to you in random order. Symmetry ratings will be scored according to a rating scale ranging from 0 to 3: 0 indicating severe asymmetry; 1 indicating moderate asymmetry; 2 indicating mild asymmetry; and 3 indicating symmetry. The entire judging process will take approximately 5 hours, excluding three, 20-minute breaks. The breaks will be scheduled beforehand and will provide you with an opportunity to relax and prepare for the next group of photographs.

Training: One session, approximately 3 hours in duration, will be devoted to training in preparation for the symmetry judging task. During the first 2 hours of the session the principal investigator will describe the parameters to be studied (visible symmetry, mild asymmetry, moderate asymmetry and severe asymmetry). In addition, the clinician and the principal investigator will assess the varying degrees of symmetry in photographs as they will appear during the data analysis and reliability stages of the investigation. The remaining 1 hour will involve independent analyses of photographs by you, the judge, and the principal investigator. This training will terminate when 95% reliability has been established between the judge and the principal investigator for assessment of selected photographs.

Other Considerations: Facial symmetry judging will be conducted on the University of Alberta campus, room 2-20, Corbett Hall. The assessment task must take place in the research office, because the photographs must remain secure there. Be assured that the execution of this research project and the conduct of its personnel are governed by the University of Alberta's policy related to ethics in human research. Any professional or academic presentations or publications derived from the study will maintain your anonymity. The symmetry rating data associated with your participation in this project will be coded and kept in a secure area accessible only to the principal investigator and her thesis committee members.

You are free to ask questions or present concerns to the principal investigator with regards to the research. You are free to withdraw from this project at any time without consequence.

By signing below, you acknowledge that you have been adequately informed about the purpose and procedures of the endeavor and the extent of your obligations as a participant in it. Your signature confirms your voluntary consent to participate and acknowledges your receipt of a copy of this information document and consent form.

______________________ ______________
Subject's signature Date

______________________ ______________________
Subject's printed name Witness

____
Principal Investigator's signature