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Biofeedback Training of Peripheral
Temperature: A Comparison of Children and Adults

C

Anne E. Pawlak

Thesis presented to the Faculty of Graduate
Studies of Carleton University in partial
fulfillment of the requirements for the
degree of Master of Arts in Psychology

Ottawa, October, 1981

The undersigned recommend to the Faculty
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Abstract

Research interest in biofeedback training of peripheral temperature expanded largely because of its potential value as a treatment of migraine headache and Raynaud's disease. However, review of the literature reveals that there is still a need to substantiate claims of skin temperature training and to isolate carefully the conditions under which this response is demonstrated. The present study was designed to correct previous inadequacies in methodology and to assess the effects of biofeedback on increasing finger temperature. Furthermore, the suggestion that children may perform better at thermal biofeedback tasks was tested directly. The present study assessed the effects of temperature feedback on finger temperature increases.

Subjects were 16 children (10 to 12 years old) and 16 adults (17 to 30 years old). Half of each group received two sessions of training to warm the middle finger of the right hand and half were control subjects, who were monitored without training for the same period of time. Each session consisted of a 16-minute baseline period followed by 24 minutes of either feedback training or control monitoring and finally 8 minutes of recovery monitoring. Training and monitoring during all phases was conducted in 90-second trials separated by 30-second intertrial intervals. Finger temperature and EMG were monitored continuously from the trained hand, and finger temperature from the untrained hand was recorded during the

intertrial interval. For trained subjects, feedback was provided by a pulsating tone varying in pitch and by a digital display of absolute temperature.

The results indicated that neither adults nor children demonstrated the ability to increase finger temperature with biofeedback training. However, children and adults did respond differently during temperature monitoring irrespective of training condition. Both age groups demonstrated a relationship between training and EMG activity. Finally, reanalysis of the data, reproducing the calculations determining dependent measures of previous research indicated the potential for bias and spurious results in such research.

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Introduction

Overview

Much of the research on biofeedback training of peripheral temperature arises from its proposed clinical utility as a treatment for migraine headache and Raynaud's disease (e.g., Sargent, Green & Walters, 1973; Blanchard & Young, 1974). Clinical investigators, including Sargent et al. (1973) provided what they called "autogenic-feedback training" which was a combination of temperature feedback, autogenic training and relaxation training. Eventually this type of treatment was identified just as "biofeedback training" and while other components remained integral parts of the package, skin temperature changes and improvements in headache were invariably attributed to the feedback. Other investigators (e.g., Diamond, Diamond-Falk & De Veno, 1978; Turin & Johnson, 1976; Wickramasekera, 1976b) have reported biofeedback-trained increases in hand or finger temperature to be accompanied by a decrease in the number or intensity of migraine headaches. Some researchers have speculated about the mechanisms accounting for such clinical improvement but this speculation seems premature given the unresolved issues surrounding the question of how biofeedback training affects peripheral temperature.

Although the literature includes several reports of successful finger and hand temperature training (e.g., Keefe & Gardner, 1979; Lynch, Hama, Kohn & Miller, 1976;

Roberts, Kewman & Macdonald, 1973; Roberts, Schuler, Bacon, Zimmerman & Patterson, 1975; Taub & Emurian, 1976), they typically neglected to control for instruction or suggestion effects, thermal imagery, reward for success, somatic mediation or relaxation. These and other cognitive and attitudinal variables have been identified as influencing peripheral temperature (King & Montgomery, 1980). Thus, there is still a need to substantiate the claims of success with temperature feedback training. If biofeedback training of temperature can be demonstrated unequivocally, then the conditions under which this response can be obtained must be carefully defined.

The present investigation examined the effects of temperature feedback on skin temperature changes compared to temperature changes of a control group of subjects who were monitored for the same period of time. In addition, there has been some speculation that children are more easily trained than adults to control their finger temperature with biofeedback (Hunter, Russell, Russell & Zimmerman, 1976; Lynch et al., 1976). This proposal has not been tested directly but arises from inter-study comparisons of the results of training procedures which used different baseline lengths, instructional sets, rewards, etc. In order to provide a direct test of this hypothesis, the present study included an age factor with half the subjects in each training group being children and half adults.

Biofeedback Training

A brief discussion of the general principles of biofeedback training is warranted before the research on voluntary hyperthermia in the fingers and hands is reviewed.

Strictly speaking, biofeedback is "feedback provided by a device that provides prompt measurement of a biological function" (Miller, 1978, p. 373). However, the term has come to refer to the entire training process which uses such feedback. The procedures include use of instrumental training methods to train subjects to modify, within biological limits, autonomic nervous system responses which are not ordinarily under voluntary control. Primary features of biofeedback training are: 1) "continuous and accurate monitoring of the physiological response to be altered; 2) immediate feedback to the subject of changes in the response; 3) motivation to alter the response" (Wickramasekera, 1976a, p. 7). Some of the responses altered to-date in animal and human subjects include EEG (e.g., Brown, 1970, 1971; Kamiya, 1968), blood pressure (e.g., Schwartz, 1972), heart rate (e.g., Engel & Chism, 1967; Frazier, 1966), muscle tension (e.g., Budzynski, 1978), salivation, urine formation and gastric motility (Miller, 1978), GSR (e.g., Kimmel, 1967, 1974; Kimmel & Hill, 1960), blood flow and skin temperature (e.g., Taub, 1977).

In the late sixties, Katkin and Murray (1968) instigated a controversy over whether or not we could demonstrate

unequivocally instrumental autonomic conditioning in humans because of the difficulty in ruling out skeletal and cognitive mediation. A whole body of research followed attempting to control for somatic mediation in biofeedback training for various responses, including heart rate, blood-pressure, and GSR changes and the evidence produced tended to support the idea that biofeedback reliably influenced the selected target response at least for the responses investigated. Blanchard and Epstein (1978) have provided an extensive review of this research.

While elaborate designs were set up to control for somatic mediation, investigators showed less concern for isolating the effects due to cognitive mediation. Kimmel (1974), for example, presented data such as post-experimental interviews during which subjects denied any awareness that anything they did was correlated with the delivery of reinforcement as evidence against a cognitive mediation hypothesis. The same investigator argued that even if it could be demonstrated that cognitive strategies alone are sufficient to produce voluntary changes in autonomic responses, they still may not be necessary (Kimmel, 1974). Again, this is an issue which warrants further investigation. From a clinical perspective, if autonomic responses can be voluntarily changed by cognitions, then attempts to train them by some other more cumbersome or impractical means such as biofeedback, seem pointless.

The underlying mechanisms of the alterations during bio-feedback training in man are not clear but usually are assumed to involve learning (Wickramasekera, 1976a). Since the procedures bear some similarities to operant conditioning, it has often been argued that what is being done is operant conditioning of covert responses. However, at least one investigator has suggested that a more complex form of learning is involved (Wickramasekera, 1976a) although the exact nature of this mechanism has yet to be determined. Because the published reports of training tend to have several other variables confounded with the feedback, it is difficult to speculate what the underlying mechanism for the change is.

Rationale for Finger Temperature Training

Peripheral temperature is of interest because at certain sites it is an indirect measure of the degree of vasoconstriction or vasodilation in the peripheral blood vessels which are primarily under the control of the autonomic nervous system. As blood vessels dilate, more blood passes through and the skin surface gets warmer; as blood vessels constrict, the skin surface gets cooler. Volume blood flow can be measured directly only by penetrating the tissue. Temperature is one measure of physical change at the skin surface which is related to volume blood flow. Two other indicators are changes in tissue opacity measured by photoplethysmographic recording and changes in volume of body

compartments measured by volume plethysmographic recording. Successful control of peripheral blood flow has been reported using both of these latter measures (Taub, 1977).

Taub (1977) discusses the relative merits of these three indices for biofeedback training suggesting that one drawback of temperature is that vasomotor changes are reflected more rapidly in plethysmographic records than in tissue temperature partly because of the insulating properties of tissue. The consequent delay in the feedback loop may produce slower learning than for more immediate feedback. However, temperature feedback has many practical advantages for clinical use over the other measures including its applicability to many body regions; it requires less expensive instruments, and the portability of the equipment makes home practice and the treatment itself more feasible.

The basis of the relationship between peripheral temperature changes and the headache improvement experienced by migraine patients in studies like those at the Menninger clinic (e.g., Sargent et al., 1973) is not clear. Initially, the effect was linked to Wolff's (1963) neurogenic theory of migraine. He suggested that during the headache phase, what causes the pain is increased pulsation or vasodilation of the temporal artery. The cold hands associated with the migraine headache is proposed as one in a chain of events associated with this vasodilated temporal artery. Friar and Beatty (1976) argue that treatments for migraine headache invariably include some

means of reducing the extracranial vasculature.

This simple hydraulic explanation, that the migraine recovery is a result of merely shifting blood to the hands in order to get it out of the head, was rejected by Green and Green (1979). They have found that "skillful patients can learn to warm their hands and at the same time maintain a migraine headache" (p. 164). Green and Green (1979) propose that it is the hypothalamus and its associated machinery that are being trained. According to their theory, the change is initiated at the limbic level, in response to the image (e.g., hands warming) signified by the feedback. The limbic response conveys signals to the hypothalamus and the pituitary gland which maintain physiological balance. More specifically, the sympathetic nervous system controls the smooth muscles of the blood vessel walls that are activated in the hands during vasoconstriction. The hypothalamus controls the sympathetic firing, which when reduced, dilates the peripheral blood vessels and increases hand temperature. Finally, Green and Green suggest that "recovery from vascular problems is not so much the learning of a vascular trick as it is a normalization of hypothalamic homeostasis" (p. 164).

Another explanation for the association between hand warming and migraine improvement questions the premise that patients voluntarily control their hand temperature. Proponents of this view emphasize the association between cool hands, or vasoconstriction in the extremities and stress,

and between warm hands and relaxation. These investigators propose that the hand warming is just part of a general autonomic response which is an index of relaxation. Biofeedback training procedures typically induce relaxation either by some direct instruction or indirectly by the atmosphere that is cultivated in the training situation. Researchers who argue for the relaxation view (e.g., Attfield & Peck, 1979; Price & Tursky, 1976) suggest that the migraine is alleviated not because patients learned to control their hand temperature, or any autonomic responses, but because they learned to relax.

Peripheral Temperature Training Research

A review of the temperature training research is presented in two sections: basic research and clinical research. This is followed by a closer examination of the relevant aspects of training.

Basic Research

Taub and Emurian (1976) demonstrated temperature self-regulation in 19 out of 21 subjects. Half were trained to increase and half to decrease hand temperature, using a variable intensity feedback light and instructions encouraging subjects to use thermal imagery. They report that the overall mean temperature change in the appropriate direction, for days four through six of training (15 min. sessions), was 2.2°F, with a maximum change for one subject of 6.5°F. They selected their "good" subjects to reverse the direction

of their self-regulatory control and reported that with longer training, subjects could produce complex patterns like altering temperature in opposite directions during successive periods in one session with demonstrated changes ranging from 8° to 15°F within 15 minutes. One subject produced a 9°F change within one minute. They found slightly greater changes in the decrease than in the increase direction ($.4^{\circ}\text{F}$) although this was not statistically significant. In a four to five month follow-up of four subjects who had been trained only in one direction, the authors found perfect retention.

Careful scrutiny of Taub and Emurian's impressive results indicates that perhaps the optimism they generated regarding the efficacy of temperature feedback training and its clinical applications was unwarranted. Although most investigators recognized the confounds of the study, such as instructions, suggestions regarding the use of thermal imagery and monetary reward (King & Montgomery, 1980), the study is regarded still as an important contribution to temperature biofeedback research and cited extensively as sound scientific evidence of voluntary changes in hand temperature.

Of even more concern than the above-mentioned confounds, is Taub and Emurian's means of calculating their reported performance measures. Their explanation for the algebraic calculations and criterion for selection of change scores is unclear. The following was determined from scrutiny of the results. Initially, they calculated for the first session

which was all baseline recording, the change between an initial stability point and the peak trial in the direction of greatest change during the next fifteen 65-second intervals (equivalent to self-regulation period during subsequent training sessions). The equivalent training day change "depended on the direction and nature of the temperature change on a given day" (p. 214). If the change was monotonic in either direction, initial temperature was subtracted from peak trial value. If the change was non-monotonic, peak trial in the instructed direction was used. Thus, it appears that whatever the nature of the temperature change, the greatest change in the instructed direction was selected as an index of performance. The final measure of change in skin temperature was calculated by subtracting the baseline day change from the training day change.

There are a number of obvious problems with the Taub and Emurian dependent measure if the present interpretation of its calculation is correct. Certainly, in selecting the greatest change in the instructed direction, they introduce an enormous bias in favour of finding an effect. Their algebraic corrections in the training changes are also questionable in the absence of analyses of baseline changes across sessions. Unfortunately, the investigators provide no information on the baseline day changes or on the nature of the changes on training days, i.e., how many monotonic (and in which direction) and non-monotonic. The severity

of these problems could be determined by using their procedures to examine some actual raw temperature training data.

Taub (1977) reported research indicating that while feedback initially is necessary for performance, after sufficient training, self-regulation of skin temperature can be as good without feedback as with it; subjects can self-regulate hand temperature for long periods of time while performing distracting tasks like playing bridge; subjects can self-regulate hand temperature in a 55°F room as well as in a 70°F room demonstrating a striking difference between the regulating hand and the non-regulating hand; subjects showed self-regulated increases in hand temperature when the untrained opposite hand was immersed in painfully cold water for ten minutes. Taub discussed the results in terms of potential cold weather applications.

Keefe (1975) used visual and auditory analogue feedback to train temperature differences between forehead and finger in both directions. Subjects (male college students) were informed of the response and the desired direction of change (four increased and four decreased finger temperature relative to forehead temperature). He determined an average change for the twelfth and final session, for the increase group of 1.9°F and 1.5°F for the decrease group. Examining performance over sessions, contrary to Taub and Emurian's (1976) results, Keefe reports relatively poor control at four sessions of training (.2°F for increase and .1°F for decrease). At eight

sessions, however, differential skin temperature control had been developed. Perhaps procedural differences between Keefe's (1975) study and Taub and Emurian's (1976) study account for their apparently different results. Among other things, their indices of temperature change were determined differently. Keefe looked at average change for the session whereas Taub and Emurian used peak changes. Also, while Taub and Emurian trained changes in absolute hand temperature, Keefe trained changes in differential temperature, between forehead and hand.

While Keefe (1975) successfully demonstrated temperature training using feedback, he unfortunately failed to separate the effects of feedback and instruction. He himself criticized previous studies that used multiple treatment procedures like thermal feedback in conjunction with instructions encouraging the use of thermal imagery, arguing that it cannot be determined from these studies what exactly is responsible for the skin temperature changes. The inclusion of a no-feedback group would reveal considerably more about the efficacy of feedback per se to peripheral temperature self-regulation.

Elder and Frentz (1978) reported successfully training male college students to increase or decrease skin temperature of the right hand over two successive one-hour daily sessions. Subjects receiving contingent feedback raised and lowered their temperature significantly while controls receiving non-

contingent feedback remained around basal level. All subjects were instructed to change the values of the digital counter in the appropriate direction. Unfortunately it is not clear from their report whether they specifically told subjects to increase or decrease their hand temperature or if the task was strictly presented in terms of controlling the digital readout. While a control group receiving non-contingent feedback was included, it is not clear what their instructions were. In addition, the adequacy of non-contingent feedback as a control has been questioned by other investigators (Hunter, Russell, Russell & Zimmerman, 1976; Kappes & Michaud, 1978).

Surwit, Shapiro and Feld (1976) trained self-regulation of increases or decreases in digital temperature and examined the relationship of this response to cardiovascular functioning. After two 45-minute baseline sessions, subjects were instructed to think of their hands as either warm or cool. Relaxation was stressed although subjects were not given any further instructions about how to control their temperature. Both hands were monitored although feedback was contingent only upon the nondominant hand and subjects were instructed to increase or decrease the temperature of their hands.

The results showed that while there were no significant differences between groups on baseline days, for treatment, decrease subjects showed an average decrease of 2.0°C from the first to the last trial block using the average of both

hands while increase subjects increased $.25^{\circ}\text{C}$ from blocks one to four.. The data was collapsed across sessions since no significant change over days was observed. Comparing dominant and non-dominant hands it was evident that the dominant hand was always warmer and temperature changes were not specific to the trained (non-dominant) hand. It is important to note that while feedback was only provided from one hand, the instructions were for subjects to warm or cool their hands. If cognitive strategies or muscular activity are what mediate the response subjects would be using strategies to regulate both hands and hence it would not be surprising that both hands showed the changes. It is difficult to tell if the following of the untrained hand indicated that this training produces a generalized response or if in fact, the elicited response is specific but the relevant element is the cognitive or muscular mediation which was directed at warming both hands.

In an attempt to control for skeletal mediation, Steptoe, Mathews and Johnston (1974) trained differential temperature in the earlobes, arguing that no skeletal muscles could cause such temperature changes. In addition, EMG was monitored from two sides of the head on the premise that muscle mediation would be picked up as differential activity on the EMG channels. By the third session, subjects produced differential temperature in their earlobes with no consistent patterns in the EMG activity emerging. The authors present

this as strong evidence that humans can self-regulate peripheral temperature changes without using somatic mediation. However, the statistically significant temperature differences between ears were very small, around 3°C , which, without a baseline measure of differential temperature, suggests that their conclusions may be premature.

Keefe and Gardner (1979) using temperature feedback and straight forward response-specific instructions, i.e. they just informed subjects of the response being monitored and the required direction of change, trained half of their subjects to increase their right hand finger temperature and half to lower it. After five 30-minute training sessions, half of the subjects had increased their finger temperature by 2.5°F and the decrease group decreased temperature by 2.9°F . In a subsequent experiment in which they trained increases only and extended the training to 20 sessions they found that after only three sessions subjects showed significant increases and further training produced no improvement.

The studies reviewed report positive results of peripheral skin (hand, finger, ear) temperature training, even with short term training of two and three sessions. In many of the studies, use of thermal imagery or auto-suggestions are either explicitly encouraged or are implicit and Keefe and Gardner (1979) suggest that this may account for changes of greater magnitude in these studies. In general, however, the indices of temperature change are small. Given some of

the questionable methods of calculating performance indices as well as the confounding variables inherent in most studies, it is apparent that more basic research is needed both to substantiate claims of significant voluntary skin temperature changes in humans and to determine the contribution of the biofeedback over and above the relaxation, suggestion and adaptation effects.

Another line of research that examined hypnosis and peripheral temperature self-regulation supports the importance of cognitive factors. Maslach, Marshall and Zimbardo (1972) presented results that "demonstrate the powerful influence that cognitive processes can exert on the autonomic nervous system" (p. 600). They found that hypnotized subjects, not given temperature feedback, were able to produce consistently large temperature differences between the two hands (an average of 4°C) whereas non-hypnotized but highly motivated subjects could not. They report that the differences produced tended to be a result of decreases in the cold hand with comparatively small increases in the warm hand.

Roberts, Kewman and Macdonald (1973) gave hypnotic suggestions to subjects highly susceptible to hypnosis, as well as auditory feedback of hand temperature and also produced reliable and statistically significant differences in temperature between the two hands (reporting differences ranging from $.3^{\circ}$ to 3.0°C). Since all six subjects received both hypnotic suggestion and biofeedback it is impossible to

determine the relative contributions of the two factors. The authors did not find any prevalent response patterns, reporting only that different subjects used different response patterns to accomplish the results. Roberts et al. (1973) propose that the magnitude of the temperature effect may be related to hypnotic depth although they did not directly test this in the above study.

In a subsequent study, Roberts, Schuler, Bacon, Zimmerman and Patterson (1975) tested the hypothesis that susceptibility and capacity for imaginative attention would enhance learning of temperature self-regulation. Eight subjects high on the Harvard Group Scale of Hypnotic Susceptibility and high on Tellegan Absorption Scale and eight subjects low on both participated in 16 one-hour training sessions. Results indicate that the susceptibility and absorption variables are not related to ability to self-regulate temperature. While for the total group there was a statistically significant fingertip differential averaged across the last eight training sessions, there were no differences on this between subjects who were high and low on the hypnosis and the absorption scales.

Taub (1977) also reports a non-significant correlation (+.51) between mean performance on fourth and fifth biofeedback temperature training days and subject's score on the Stanford Hypnotic Susceptibility Scale. However, he argues that this does not imply that hypnosis or hypnotic suggestion

will not enhance temperature self-regulation for an individual. As an example, he cites one case of a poor performer who later improved with hypnosis.

The hypnosis research attests to the importance of the role of cognitions in temperature self-regulation. Given that these effects have been demonstrated with hypnosis and without external feedback (e.g., Maslach et al., 1972), with both hypnosis and feedback (e.g., Roberts et al., 1973) and with feedback only (e.g., Roberts et al., 1977), the contingencies for the acquisition cannot be any more attributed to the biofeedback than to instructions, auto-suggestions, or cognitive strategies. However, in this line of research as in the biofeedback work, the mechanism underlying the change is still not clear. While investigators present their results as evidence of voluntary finger temperature control, such conclusions do not seem justified. For example, Barber (1974) argues that in training differential temperature in the two hands, the result could be simply the effect of subjects constricting the muscles in one hand and relaxing them in the other.

Clinical Research

Most of the clinical research on training of voluntary skin temperature changes in humans tested the efficacy of training on headache improvement in migraine patients. The earlier migraine research from the Menninger clinic has already been mentioned (Sargent, Green & Walters, 1973). In

spite of the methodological problems in this initial work, e.g., no baseline data, unsystematic data gathering, a lot of variability in the data, interrater disagreements and no standard statistical assessments (Blanchard & Epstein, 1978), subsequent studies supported the therapeutic advantages of finger warming for migraine improvement.

Wickramasekera (1976b) demonstrated headache improvement in two migraine patients who had been trained to warm their fingers using temperature feedback and no autogenic training. Self-regulated hand-warming was clearly demonstrated by the third and fourth weeks and was accompanied by decreases in headache frequency and intensity. Wickramasekera argues that attention-placebo effects are an unlikely explanation for their improvement since the same patients had been unresponsive to medication, psychotherapies and lengthy frontal EMG biofeedback training.

Johnson and Turin (1975) in a case study report positive results in thermal feedback treatment of migraine headache and later Turin and Johnson (1976) trained seven migraine sufferers in temperature control of the index finger of the dominant hand using biofeedback and home practice without autogenic training. Three of the subjects were trained to cool for six weeks, then to warm for six to eight weeks, while the other four subjects were trained only to warm. They were instructed to warm or cool their finger when they felt a headache come on. It was found that only two out of the three

could cool although all seven could learn to increase peripheral temperature. Headache activity increased or stayed the same for cooling but decreased when these subjects later learned to warm. Turin and Johnson found significant decreases in three indices of migraine activity for the group and concluded that finger temperature warming effectively reduces migraine activity independent of placebo.

Their results, concerning direction of easiest change are opposite to those reported for nonclinical subjects who show greater ease in decreasing than in increasing temperature. The discrepancy could be explained by differences in initial temperatures. Although Turin and Johnson (1976) do not report basal temperatures, migraine sufferers are reported to have very cold hands during headache periods. It is likely that these subjects already were very cold in the extremities and therefore had difficulty decreasing their finger temperature further. By the same argument, these subjects warmed more easily than nonclinical subjects. Additionally, the conclusion that the finger warming effectively reduced the migraine activity perhaps is misleading since relaxation and other possible mediation effects could not be ruled out in this study. The results do not indicate that the hand-warming is the critical component which alleviates the headache.

Other studies have evaluated various temperature bio-feedback treatment packages in relation to relaxation

training for treatment of migraine headaches (Andreychuk & Skriver, 1975; Attfield & Peck, 1979; Blanchard, Theobald, Williamson, Silver & Brown, 1978). These results all indicated that relaxation training is at least as effective as finger temperature biofeedback training for alleviating headaches. Unfortunately not all of these studies reported data on temperature changes, and those that did, yield inconsistent data. While Price and Tursky (1976) found that hand temperatures increase as much in the relaxation condition and in the false feedback condition as it did in the contingent feedback condition, Attfield and Peck (1979) reported more finger warming in the feedback condition than in the relaxation group. However, contrary to what past research would predict, in this latter study the relaxation group who showed less warming, surpassed the feedback group in headache improvement. Kewman (cited in Turk, Meichenbaum & Berman, 1979) also questioned the specific effects of hand warming on headache reduction reporting that migraine patients who were trained to lower finger temperature as well as those who received no training showed as much headache reduction as those who were trained to raise finger temperature.

Werbach and Sandweiss (1978) proposed that any method which reduces sympathetic activity may help to abort migraine headache. In their study they used any one of three biofeedback modalities - digital temperature, palmar skin conductance,

or frontal EMG - along with other therapeutic techniques, to train a relaxation response. They report an improvement rate similar to that found in other studies although hand-warming was no more important for this improvement than any of the other responses.

In summary, research on migraine patients and voluntary hyperthermia in the hands and fingers further clouds the contingencies controlling the temperature self-regulation. Although some investigators such as Diamond, Diamond-Falk and De Veno (1978) (the Diamond Headache Clinic) have argued that temperature feedback training is an effective treatment for migraine headache and relaxation is an important predisposition for the hand warming response, the data show a similar proportion of migraine patients responding positively to relaxation training as to hand temperature training. Blanchard and Epstein (1978) proposed that since finger temperature tends to increase when normal subjects are given relaxation training and decreases under stress, "the final common pathway to action in migraine improvement for both relaxation training and biofeedback training is a relaxation response which includes peripheral vasodilation and hence skin temperature increase" (p. 83).

Research results with Raynaud's patients are consistent with the migraine work. Although anecdotal case reports attest to the efficacy of temperature feedback training in alleviating the painful symptoms (Blanchard & Haynes, 1975;

Jacobson, Hackett, Surman & Silverberg, 1973), temperature biofeedback does not fare so well in the controlled outcome studies. Although subjects are trained to warm their hands using temperature feedback, this response is not unique to the feedback training.

Following successful treatment of a single Raynaud's patient, Surwit, Pilon and Fenton (1978) trained 30 female Raynaud patients to control their digital skin temperature using autogenic training or both autogenic and peripheral temperature feedback training. Before and after treatment, all subjects underwent stress tests during which they were to keep their hands as warm as they could while room temperature was lowered drastically. The results indicated that for both groups skin temperature was significantly higher and number of attacks significantly lower during the stress test after treatment than before.

Other research is cited in the same paper (Surwit et al., 1978) demonstrating that "general relaxation techniques provide the same degree of effectiveness as more specific biofeedback techniques in the treatment of hypertension" (Surwit et al., 1978) and other disorders (Silver & Blanchard, 1978). The authors conclude that it is still not clear why autogenic training successfully produces voluntary vasodilation, although they speculate that since muscle relaxation is the primary focus, sympathetic activity is probably reduced somewhat, to facilitate peripheral vasodilation when attention

is drawn to sensations of warmth and heaviness.

Specificity of the Temperature Change Response

The issue of response specificity is essential to understanding the mechanisms underlying peripheral temperature training. Studies examining specificity of response also relate directly to attempts to establish the role of general relaxation in producing past results in temperature training.

While relaxation usually has been viewed as important to biofeedback training, opinions differ as to its precise role in temperature control and in therapeutic benefit. Wickramasekera (1976c) suggested that the relaxed state may reduce the noise or interference in the system and therefore increase the impact of any new sensory-verbal input. He cited Barber's (1970) work which indicates that relaxation instructions are one of the significant antecedent variables which increase hypnotic suggestibility and he noted the importance of relaxation as a set in systematic desensitization. Wickramasekera (1976c) proposed that in the biofeedback situation, as in the above situations, relaxation serves to increase the subject's responsivity to verbal-sensory input. Another approach to this relationship between hand temperature training and relaxation which has already been mentioned is that the response being trained is a relaxation response and peripheral vasodilation is simply one aspect of that (e.g., Blanchard et al., 1977).

Taub (1977), however, suggests that the response being trained in his laboratory is not the same as that reported by Sargent et al. (1972) at the Menninger Clinic or by other researchers incorporating autogenic or relaxation techniques into their training. He argues that he has been training specific control of blood flow in a localized region and has found control very specific to the feedback site. Even to generalize the response to the whole hand, multiple feedback loci had to be used. A generalized relaxation response, however, would have a more diffuse effect, i.e., it would not result in warming in only one finger tip. According to Taub's interpretations, the Menninger studies were using autogenic phrases and temperature feedback to produce a generalized relaxation effect, using the increase in hand temperature as a useful indicator of relaxation. "It would probably not be possible to obtain a localized blood flow change when autogenic phrases are used to induce a generalized state of relaxation, no matter what type of feedback were employed" (Taub, 1977, p. 290).

Taub (1977) suggests that the two labs are therefore using two different techniques and while both techniques apparently work in the treatment of migraine, they involve different mechanisms. Hand warming with autogenic phrases is effective because it induces a state of relaxation and thereby "reduces the level of the postulated migraine triggering factor" whereas the other technique works by

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"vasoconstricting vessels that would otherwise produce pain because of excessive vasodilation" (p. 291).

Reports on the response specificity in the different studies have not been consistent. Surwit et al. (1976) trained subjects with feedback only, i.e., no autogenic training. They report that even after nine training sessions there was no evidence of specificity. The temperature changes were bilateral although the feedback was provided from only one hand. The problem in interpretation here, since verbal instructions were to warm or cool their hands, have already been discussed.

Roberts et al. (1975) found a relationship between the degree of specificity and performance. In sessions where better performance occurred there was a low or negative correlation between the two hands. They also found, however, that learning was associated with a higher correlation between the finger tip differential temperature and the wrist differential, "suggesting that control was exercised over fairly large areas of the distal portions of the arms" (p. 277).

The specificity of the trained response may provide a clue to the mechanism underlying the change. In the present investigation, data were gathered from successive rather than simultaneous recordings from the right (trained) and left (untrained) hands and from EMG recordings from the right hand only. Although these data could not provide conclusive

indications of specificity, the measures were selected to provide optimal information within the constraints of the apparatus available.

Individual Differences

Trainee's Attitude

Research on individual variables predicting successful biofeedback trainees has produced agreement that subject's expectation of success is an important variable. Such expectation is also a central factor in most behaviour therapies. For example, Orne (1970) found an interaction between placebo/treatment and expectancy which indicated that a positive set significantly increases the probability that an effective treatment will be more effective than placebo control. Budzynski (1978) stressed the importance of establishing positive yet realistic expectancy in biofeedback treatment. Schwartz (1973) proposed that "positive expectations on the part of the patient may well be a prerequisite for positive gains". A few investigators (Hunter et al., 1976; Werder, 1978) have proposed that children's positive expectations or lack of skepticism in the biofeedback situation may well be related to their high success rate.

Leeb, Fahrion and French (1974) included expectation/motivation as an independent variable, manipulating set of subjects by administering positive, negative or neutral instructions. They found this had a significant influence on subject's ability to learn hand temperature control. In their

migraine studies Sargent et al. (1973) noted that while they did not observe a specific "migraine personality", subjects who believe they can influence their bodily processes learn faster than those who do not. While Roberts et al. (1975) found that neither hypnotic susceptibility nor absorption measures were related to ability to produce temperature differences between the two hands, post hoc analysis revealed that variables like autonomic responsivity, confidence and belief in the phenomenon or in their own ability and the nature of their interaction with the experimenter were relevant.

Taub and Emurian (1976) reported that a relaxed attitude was important and trying too hard was counter-productive. They found no correlation with any of the MMPI scales. Thompson (cited in Taub, 1977) found a correlation between temperature self-regulatory ability and Spielberger State-Trait Anxiety Inventory and Barratt Impulsiveness Scales. High-anxious subjects manifested larger initial increases in skin temperature and the best learners were high-impulsive low-anxious.

Experimenter

Dispositional variables of the experimenter or trainer have been posited as influencing the degree to which subjects learn control (Roberts et al. 1975). With a friendly informal experimenter, who appeared convinced of the feasibility of the treatment and conveyed this to the subject, 19 out of 21 subjects achieved hand temperature autoregulation. On the

other hand, with one who was cold and formal and who conveyed a negative attitude regarding the subject's ability to accomplish the task, only 2 out of 22 subjects succeeded (Taub, 1977).

Sex

There seems to be scant evidence for sex differences on visceral learning tasks. Taub and Emurian (1976) reported a difference which they call "not quite significant" between males and females in the magnitude of temperature self-control achieved. The magnitude of the difference between the warm trials and the cool trials was $.8^{\circ}\text{F}$ greater for females than for males. In their investigation of temperature autoregulation Surwit et al. (1976) examined males and females separately for ability to vasodilate and vasoconstrict. They cited evidence that "females have more difficulty with peripheral circulation and show higher incidence of peripheral vasospastic problems than do men" (p. 202). The only sex differences they report in their study involved a group (warm/cool) x sex x session interaction for the heart rate response. Females instructed to warm their hands tended to show an increase in heart rate over days. Thus, there seems to be only very weak evidence of sex differences. In the present study an equal number of males and females were run but sex of subject is not an important variable in the study.

Age

There has been some speculation that age is a relevant factor in biofeedback training performance. Most of the research on biofeedback has been done with adult subjects and there have been few controlled group outcome studies using biofeedback techniques on children. Consequently little is known about the ability of normal children to learn biofeedback skills. However, the few investigators studying children report a remarkable ability among this younger population to acquire self-regulation of autonomic responses. Lynch, Hama, Kohn and Miller (1976) reported an attempt to replicate Taub and Emurian (1976) in training adults to self-regulate hand temperatures. After they failed to find any evidence of the effect with a few adults even after 18 daily sessions of training, they decided to investigate whether or not skin temperature control could be reliably acquired by children.

Lynch et al. (1976) tested unselected normal children between six and twelve years old in two experiments. The first experiment involved one female and three males (from 9 to 12 years old) who were trained to control the temperature difference between two hands and the second took the two best performers from the first experiment and trained a temperature difference between two fingers of the same hand. After 12 sessions, three out of the four subjects produced reliable temperature differences between the two hands.

The second experiment consisted of eight sessions and subjects warmed the second finger relative to the fourth for four randomly selected sessions and warmed the fourth relative to the second for the other four sessions. Although both subjects showed changes in the correct direction, statistical significance was achieved by only one of the subjects. Lynch and his associates felt their study demonstrated the remarkable ability of children to learn control over very specific vasomotor responses in contrast to their previous lack of success with adults. However, in light of the very small select sample, their results can be interpreted as suggestive at best and definitely require substantiation.

Hunter, Russell, Russell and Zimmerman (1976) conducted a large study investigating the abilities of 30 learning disabled and 30 normal children to learn control of finger-tip temperature increases via biofeedback. The learning disabled and the normal children were matched on age, grade, race, sex, intelligence level (estimated by the teacher) and socioeconomic class (low). One group (half L.D. and half normal) received consistent reinforcement contingent upon finger-tip temperature increases and the other, the yoked-control group, received mixed reinforcement, feedback not contingent upon any specific response.

Over five consecutive training days, subjects received feedback from a variable intensity lamp and they were reinforced by a toy train going around the track when they

reached the criterion finger tip temperature increase of .5°F from baseline. Before training, subjects were told to hold the temperature probe gently and to try to warm their fingers to make the light brighter. The results of training indicated, as the investigators expected, that children who received consistent reinforcement did better as indicated by both performance and learning measures than those in the mixed group. An unexpected finding was that learning disabled had higher performance measures on the average than normal children.

Another interesting finding was a significant difference among the three grade levels in performance, the youngest subjects (seven year olds) performing better than the eight and nine year olds. Since the younger group had a higher average intelligence level this could have been a mediating variable although intelligence was not found in general to predict performance or learning. Hunter and her colleagues feel that while intelligence cannot be ruled out, they favour the hypothesis that younger children are less skeptical about their ability to succeed at the task than older ones. Particularly among the learning disabled, older children have a longer history of failure in school than younger and so come to the experiment with more negative expectations. Other investigators have suggested that subject expectation is a relevant variable in predicting success in adult bio-feedback training.

Because of some questionable procedural points, inferences based on the Hunter et al. (1976) results must be made cautiously. They allowed only a very brief 2-minute baseline recording period. Even with inclusion of a control group, this provides an inadequate baseline measure. Discussion of this point is presented in detail later in the paper. Hunter et al. (1976) argue that the short baseline was unavoidable because of the "motor impersistence" of the subjects. Such an excuse does little to aid interpretation of the results. Further, it seems incompatible that the same investigators who report that the subjects are restless incorporate a monitoring procedure which allows the subjects to hold the temperature probe between their fingers.

Finger temperature training as a treatment for children suffering with migraine headache has also been investigated in a few studies. Werder (1978) quoted that while most of this kind of research has focused on the adult population, migraine does occur in children. She gives what she feels are conservative estimates of the incidence of migraine. By age five the incidence is 1%, by age 11 it is 5%. Migraine is a greater problem in children even than in adults because of their general intolerance of most analgesics and hence it is urgent to develop some non-drug approaches.

Although few investigators have examined the efficacy of this treatment for children with migraine, those that have are optimistic. Peper and Grossman (1974) trained two

migraine children (females) using thermal biofeedback and autogenic techniques and reported that the children learned very rapidly. Diamond and Franklin (1977) trained 36 migraine children with autogenic techniques and EMG and temperature feedback with home practice. Twenty-six of the patients were evaluated as showing "good results" and the remainder were fair or showed no change.

Werder (1978) trained four migraine patients, ages 10 to 17, to increase skin temperature of the right index finger using visual temperature feedback with autogenic-relaxation procedures. She reported that the patients rapidly learned to increase their hand temperature (2° to 5°F by the second to fourth sessions). The temperature self-regulation was accompanied by substantial reductions in headache activity which was maintained at six month follow-ups. Patients reported continued use of relaxation-autogenic procedures after the initial biofeedback training.

The positive results reported in these clinical studies are presented as evidence of a promising non-drug treatment for childhood migraine. Werder discusses the ease with which the children learned self-regulation of hand temperature. However, the problem of confounding the relaxation with the biofeedback training exists in the child research as it does in the adult work. These studies include relaxation and autogenic phrases with the biofeedback training, so it is difficult to separate the effects of the different treatment components.

The bottom line in these studies, in spite of the procedural confounds, is the reported improvement in headache. However, this too must be viewed with some reservation. In their retrospective study of diagnosis and treatment of migraine in children, Prensky and Sommer (1979) identify the high remission rate as a major difficulty in evaluating effects of long term therapy on childhood migraine. Proper controls are particularly difficult in clinical research and so frequently are not included. When controls are overlooked, as in the studies reviewed, it is impossible to determine how much of the improvement resulted from the treatment and how much is spontaneous remission.

Investigators studying temperature feedback training of children have reported that children train better than adults. Werder speculates that this may be because children are less skeptical than adults about the possibility of autonomic control and they do not tend to complicate the process or impose elaborate visualization and verbal procedures as adults often do. However, amidst this speculation, whether or not children actually demonstrate a greater ability than adults to self-regulate hand temperature has not been directly tested. The present investigation compared the performances of children and adults in voluntary finger hyperthermia.

Procedural Considerations

To provide a rationale for the procedures selected for the present study, a brief review of the methodological aspects of previous studies are presented.

Number of Training Sessions

Taub and Emurian (1976) reported that most adults learn temperature control in four 15-minute sessions of temperature feedback training. Hunter et al. (1976) therefore trained children for five 15-minute sessions and found that sufficient for reliable increases to be shown. Their normal children did most of their learning between day one and day three and levelled off after that.

Taub (1977) later confirmed that, for adults at least, training to a level of unequivocal acquisition rarely required more than four training periods. Elder and Frentz (1978) showed clear self-regulation of temperature in two one-hour sessions and Werder (1978) used five sessions on successive days or six bi-weekly sessions. Other investigators have used more sessions. Lynch et al. (1976) trained their subjects for 12 sessions although six of these were for warming right hand relative to left and for six they warmed left relative to right.

Keefe and Gardner (1979) examined the effects of short versus long-term training and reported that three training days were sufficient to produce significant increases in digital temperature and further training up to 20 sessions produced no improvement. The evidence indicated that three

training sessions would be ample to demonstrate the response.

A small pilot study was conducted in the present investigation. Subjects were trained for one to three sessions. The results indicated that any evidence of warming was obtained in the first two sessions. In no case did the third session add any information. Therefore, given the practical considerations and the absence of evidence for the advantage of the third session, it was decided to train subjects for two sessions.

Spacing of Sessions

A few studies have directly tested the effect of varying the spacing of thermal training sessions. However, these were all clinical studies that indicated no difference in clinical improvement for spaced versus frequent sessions (Diamond & Franklin, 1975; Pearse, Walters & Sargent, 1975; Surwit et al., 1976). Concerning the effect on temperature per se, while there is no empirically established consensus for optimal spacing of training sessions, this does not appear to be a crucial variable. Sessions range from daily to weekly with no apparent advantage of one schedule over another. Many investigators (e.g., Hunter et al., 1976) use consecutive daily sessions. In the present study, sessions were conducted as much as possible, on consecutive days.

Type and Amount of Feedback

Early investigators found binary yes-no type feedback

unsatisfactory and that continuous tracking of the response with precise and immediate information feedback is crucial to the training. Therefore most studies use analogue information feedback. The feedback is usually a tone which varies in pitch, a light (or lights) which varies in brightness or a digital display of the absolute or differential level of the response being trained.

Other feedback modes have been used, such as needle deflections on a panel meter or a train running around a track (Hunter et al., 1976). Where some extrinsic reward is used in the training, this also usually serves as a feedback source. For example, Lynch et al. (1976) used a digital counter which displayed earned money rewards throughout training.

Most investigations of the optimal amount of feedback have involved heart-rate training (Miller, 1978), and these studies report that amount and type of feedback influence learning to increase but not to decrease heart rate. Elder, Welsh, Longacre and McAfee (1977) in a study on blood pressure found that more feedback information is better than less. There has been no research that this investigator knows of on this issue as it pertains to temperature training.

The biofeedback condition in the present investigation included two sources of feedback. A low volume tone which varied in pitch with temperature informed subjects of temperature changes and a digital display informed them of their absolute finger temperature.

Experimental Controls

Baseline. Establishing a stable baseline is essential in biofeedback research; particularly in training responses, like hand temperature, which are closely related to physiological arousal. It is well known that during stress, hand and finger temperatures tend to decrease and during relaxation, they tend to increase (Boudewyns, 1976; Crawford, Friesen, Tomlinson-Keasey, 1977). Vasoconstriction is an adaptive biological response to stress. The blood moving from the periphery to the deep muscles prepares the organism for flight (Diamond et al., 1978). Taub (1977) argued that anxiety, as a result of the laboratory situation tends to decrease the temperature of the extremities. Therefore, when given time to adjust to the situation, tense subjects will relax and hand temperature will increase. Taub stresses the importance of the initial relaxation period before the training session begins.

Other investigators have argued that most of the research reported does not allow a long enough baseline to demonstrate a change in temperature as a result of feedback, over and above what would have occurred anyway in a proper baseline (Packer & Selekman, note 1; Surwit, Shapiro & Feld, 1976). In their study of EMG and temperature biofeedback training, Packer and Selekman (note 1) focused on changes during baseline. Their first three sessions each consisted of 75-minute baselines, and training sessions included 30 minutes of

baseline before each training phase, 30 minutes of training, then a 15-minute recovery baseline. A frequent baseline pattern, they observed, was an increase in temperature for the first 15-minutes then it leveled off or decreased for the remainder of the baseline. They argue that at least a 15-minute baseline is required before effects due to the temperature training can be demonstrated. A few of the studies reviewed met this criterion. Taub and Emurian (1976) and Surwit et al. (1976) both allowed from 10 to 30 minutes of baseline recording prior to training.

Typically the baselines reported in the literature are shorter than these. Keefe (1975) used a three-minute baseline. Hunter et al. (1976) allowed only a two-minute baseline at the beginning of each training session. They report that children were not tested until they had been in the temperature controlled environment of the school for at least 20 minutes thereby controlling for artifacts resulting from different ambient temperatures. They argue that they were forced to select brief baselines and short training trials because of the difficulty in keeping many of their children still for any longer. They feel that their baselines are justified since their mean baseline temperatures were in accord with those reported for adult subjects in whom generally lengthier baselines were obtained. Unfortunately, they do not specify how lengthy the adult comparison baselines were.

In their study, Lynch et al. (1976) preceded the ten-minute practice period with a three-minute baseline, using the last baseline minute as the comparison for the training temperature. They argue that in training the two hands differentially, they circumvent the baseline criticism since you would expect both hands to be subject to this "relaxation" or baseline effect. However, it is not clear that either such differential training, or a control group, is an adequate substitute for an appropriate baseline. In the present investigation, 16 minutes of baseline recording preceded the training periods for each session.

Including lengthier baseline periods introduces the problem of subject boredom. Obviously for the majority of studies which used brief baselines, this was not an issue. Some of those with longer baselines attempted to allay boredom and promote relaxation by playing soft, innocuous music during this period. Taub and Emurian (1976) played music unless subjects expressed a desire for them not to. In the present study, to maintain standardized procedure, quiet music was played for all subjects during baseline.

Control Group. Even though an adequate baseline period was chosen for the present study, it might still be argued that temperature changes observed during the training period, might have occurred without any training, i.e., as a result of natural temperature fluctuations. Therefore, half of the participants were assigned to a control group. During the

training period-equivalent, while temperature and EMG was monitored they were lying comfortably and quietly but received no feedback training.

Control for Mediation

Taub and Emurian (1976) discuss pilot work and previous studies that look at controls for cheating and somatic mediation which suggest these are unlikely explanations for the effect they obtained. They argued that temperature changes resulting from gross maneuvers of the arms and hands were small compared to those later manifested during training sessions. They placed a plexiglass box over the self-regulating hand for some subjects, eliminating the possibility that these subjects could be influencing the thermistors by some external mediation such as by blowing on them. Even when the experimenter remained in the room observing the subjects to control for movement artifact, self-regulatory control over skin temperature was still demonstrated.

Taub and Emurian (1976) argue that bi-directional training controls somewhat for artifact, suggesting that it is unlikely that some "trick" or two different tricks would allow subjects to control their temperature equally well in either direction. Other investigators, such as Barber (1974) disagree. He argues that differential muscle relaxation and tensing can produce differential temperature effects. Also, it is questionable that subjects can control their temperature equally well in either direction. Further

discussion of this issue is presented below. As further evidence against a muscular mediation hypothesis, Taub and Emurian report no correlation between forearm EMG and finger temperature for 8 out of 10 sessions and only moderate correlation for 2 sessions for 2 bi-directional subjects.

Steptoe, Mathews and Johnston (1974) also used EMG monitoring to assess muscular mediation in peripheral temperature self-regulation. While training temperature difference between the ears, they monitored EMG activity from both sides of the head and found no consistent pattern in the EMG data to account for the differential ear temperature demonstrated.

Given the concern expressed in the literature over the muscular mediation issue, it is surprising that there is so little data reported on EMG activity during temperature training. In an effort to examine the muscular mediation hypothesis, EMG was monitored from the trained hand during the present investigation.

Instructions

Several investigators have discussed the importance of instructions for performance in biofeedback training (Wickramasekera, 1976a). This is consistent with the evidence indicating the relevance of subjects' expectation of success and their motivation to perform the task. Taub

(1977) demonstrated that positive instructions, that convey confidence that the subjects can succeed would facilitate acquisition of self-regulation.

Wickramasekera (1976a) suggests that as well as the instructions providing the subject with a credible expectational set, they should be aimed at alleviating any anxiety the subject has about the training situation. They should include some explanation or description of the training to familiarize the trainee with the procedure, to eliminate the mystery and put the subject more at ease. "Passive volition" has been used to describe the optimal attitude with which a subject should approach biofeedback training (Wickramasekera, 1976b; Taub & Emurian, 1976) and this should be encouraged through the instructions.

There has been a great deal of variability in the content of instructions for biofeedback training in terms of providing cognitive strategies and relaxation techniques. For example, while some investigators encourage the use of thermal imagery (e.g., Meichenbaum, 1976; Taub & Emurian, 1976) others argue that this may in fact impair learning (e.g., Surwit, 1973). As a consequence, Hunter et al. (1976) phrased their instructions in terms of increasing the light intensity and moving the train, by warming the fingers, but did not tell subjects how to do it. Lynch et al. (1976) presented the temperature control task to their subjects as a "game of moving the needle" by warming one hand relative to

the other. Keefe and Gardner (1979) used straight forward response-specific instructions, just informing subjects of the response being monitored and the required direction of change.

On the other hand, there is evidence suggesting a positive effect of imagery and instructions devised to enhance it. Luria (1968) reported the case of a subject with very vivid imagery who could speed his heart rate from 70 to 72, to 80 to 96 and finally to 100 beats per minute by imagining he was running for a train. The same subject could produce a 3.5°C difference in temperature between the two hands by imagining his right hand was on a hot stove and his left was on a block of ice. Taub (1977) found thermal imagery alone was insufficient to enable most people to self-regulate skin temperature, although a slide presentation of thermally relevant scenes with simultaneous verbal suggestions from the experimenter does appear to enhance self-regulation in conjunction with biofeedback. He also notes, however, that sometimes instructions that involve suggestions concerning thermal sensations, for example autogenic training, may produce temperature changes in the extremities even when no feedback is provided. On the other hand, he argues that subjects provided temperature feedback, but misinformed that the feedback was contingent upon skin conductance changes, showed no impairment in learning compared to correctly instructed subjects. The

present study was instigated largely because of discrepancies like these. Since instructional effects may be so potent, children and adult biofeedback subjects were provided with the same instructional set. Subjects were instructed to get comfortable and relaxed but, since this manipulation has been posited as the most potent influence of temperature change (Packer & Selekman, note 1), this instruction was common to all phases of training for all subjects.

Before training, experimental subjects were informed that this is an experiment in training finger tip temperature self-regulation -- an ability that most people can acquire fairly easily. It was emphasized that most people find it simple to learn, that it is effortless. Subjects in the control condition were told that the study was investigating physiological responses during rest and relaxation. Control and feedback subjects were not administered their respective instructions until after the baseline period. All subjects received the same general introduction and baseline instructions.

Dependent Variables

Direction of Temperature Change

Biofeedback temperature training acquired popular interest with a number of studies training subjects to produce temperature differences between two thermistor sites. Sargent et al. (1972) initially trained subjects to increase finger temperature relative to forehead temperature but found

that since it was the finger temperature that did all the changing, providing feedback from the fingers alone was just as effective as feedback from both sites. Other investigators trained subjects to differentially control one hand or finger relative to the other. Lynch et al. (1976) trained subjects to cool the dominant hand and warm the other for the first six sessions and then to reverse this, to warm the dominant hand and to cool the other, for the last six sessions. They found that the difference was usually accomplished by a cooling response, i.e. most of the responses were the result of the two hands cooling differentially. In their second experiment, they used two fingers on the same hand and for four randomly selected sessions warmed one relative to the other and for the remaining four sessions reversed the direction of change. Although both subjects showed changes in the correct directions, for only one of the two was this statistically significant.

In their study using adults, Surwit, Shapiro and Feld (1976) conditioned both increases and decreases in hand temperature and found substantial differences in subjects' proficiency depending on the direction. The average decrease in hand temperature was 2°C with one subject demonstrating a decrease of 10°C . The average increase response was only $.25^{\circ}\text{C}$, a very slight change over baseline. Suspecting that this small increase may be due to a ceiling effect, these investigators conducted a second study in which they lowered

basal surface temperature by lowering room temperature. They found that subjects performed worse, showing no increase in hand temperature under these conditions, disconfirming their suspicion of a ceiling effect.

Hunter et al. (1976) trained temperature increases only. While it could be argued that a demonstration of temperature control would require both increases and decreases, the authors' reasoned that increasing temperature is more difficult than decreasing. The artifacts that have been discussed in the context of temperature training, like changes in respiration or muscle tension cause peripheral vasoconstriction and therefore cooling rather than warming. In the Maslach et al. (1972) study, where hypnotized subjects (no feedback) could produce significant differences between their two hands, the investigators report that the difference was usually a result of decreases in the "cold" hand with comparatively small increases in the warm hand.

A review of the evidence tends to suggest that at least for normal subjects it is easier to decrease hand temperature (vasoconstrict) whereas increases are difficult and typically small. Some investigators report increases and decreases of roughly the same magnitude. For example, Keefe (1975) and Keefe and Gardner (1979) found an average change of 1°C in either direction. The problem of inadequate baselines, in these studies, has already been discussed. Nonetheless, most of the data point in the opposite direction. Taub (1977)

noted that most investigators train vasoconstriction rather than vasodilation because it is easier to elicit. This is consistent with other evidence, provided by studies training normal subjects to regulate heart rate, that sympathetic arousal is easier to elicit than the opposite response (Blanchard & Epstein, 1978). It seems that only individuals whose base rate is far from a normal baseline can produce large scale decreases in heart rate or large scale increases in finger temperature. As a consequence, Blanchard and Epstein (1978) have noted that "most of the basic research is on the response which has the least clinical utility" (p. 76). The present study focused on the warming response in the fingers, the response which most researchers suggest has clinical utility.

Indices of Temperature Change

A wide variety of dependent measures have been calculated to assess degree of temperature change. Lynch et al. (1976) took the mean change in the temperature difference of the two hands from the last baseline minute to the last five minutes of training in each session. Hunter et al. (1976) obtained two dependent measures. They calculated performance, as change in temperature within a trial by subtracting the first reading from the third (last) reading for each trial and averaged this across trials to get mean daily performance and across sessions to get mean overall performance. In addition a learning measure was calculated as the slope of

the regression line of performance on days.

Attfield and Peck (1979) calculated the mean for the last four minutes of the stabilization phase and used changes with respect to this stability point every 30 seconds during training. They then summed these difference scores within and across sessions. Surwit et al. (1978) took a reading every 85 seconds and averaged them into 7-minute time blocks. In the present study, sessions were divided into 90-second trials and the primary dependent measure, change in right-hand temperature was calculated by subtracting the first reading from the last reading for each trial, then calculating the average change for each block of 4 trials. Temperature was monitored from the middle finger of the left (untrained) hand as well as from the right (trained) hand and EMG was recorded from the back of the trained hand. Measures of left-hand temperature and of EMG were used to assess the specificity of the right-temperature responses and to determine their relationship to muscle activity.

Present Study

To summarize, the present study investigated the ability of adults and children to regulate finger temperature increases using biofeedback training. A review of research in the area suggests that the feedback may be confounded with several other variables and thus may not be the critical variable.

While it has been suggested by some investigators that children are able to learn the response more easily than adults (Lynch et al. 1976; Werder, 1979), no studies have yet directly tested this hypothesis. Therefore, in the present investigation, the responses of adults were compared to those of children in feedback and control conditions.

The study was designed to:

1. test the efficacy of temperature feedback training, while eliminating some confounding variables found in past studies;
2. test the hypotheses that children perform better than adults during temperature feedback training;
3. to examine the specificity of any warming effect by measuring temperature from the untrained hand and EMG from the trained hand.

Method

Subjects

All participants were healthy right-handed subjects who reported not suffering from migraine headaches nor circulatory-related ailments. Sixteen children between 10 and 12 years old and 16 adults between 17 and 30, were randomly assigned to either the temperature feedback training or the control condition. The random assignment was constrained by an effort to match the training groups on age and sex.

Adult subjects were recruited from an introductory psychology course and the children all attended schools in the immediate neighbourhood of the university and were recruited through contacts with their parents. All subjects received \$10 for participating in two 1 to 1½ hour sessions.

Apparatus

An Autogen 2000B (Autogenic Systems Inc.) monitored finger temperature and provided auditory feedback. An external speaker amplified a pulsating tone transmitted from the 2000B, which dropped in pitch when temperature increased and increased in pitch when temperature dropped. An Autogen 1700 monitored EMG from the back of the right hand and an Autogen 5600 Data Acquisition Centre recorded all data and provided visual (digital) feedback of finger temperature. Responses were monitored by tiny epoxy thermistors, taped to the tip of the middle finger of each hand and by a set of EMG electrodes attached to the back of the right hand.

Appendix A contains the details of the apparatus and hook-up procedures. Throughout the session subjects were well supported in a semi-reclining position on a cot. They placed each hand in a cardboard template which kept the fingers comfortably separated and ensured that they maintained a standard hand position. During baseline, all subjects heard quiet music.

Experimental Design

The study was designed as a split-plot factorial with age group and training group as the between-subject factors and sessions and trials as within-subject factors. For purposes of analysis the trials were collapsed into blocks of 4 and into phases (baseline or training). The experiment involved two sessions each of which consisted of 16 minutes of baseline monitoring and 24 minutes of training or control monitoring. All monitoring was divided into 90-second trials separated by 30-second intertrial intervals. The baseline consisted of 8 such trials and the training phase consisted of 12. Following the training phase an additional 4 trials (8 minutes) of monitoring, similar to that during the baseline was done (in order to collect data on temperature changes during recovery).

Procedure

When subjects entered the room on the first day, they were given a general introduction to the Autogen equipment, thermistors and electrodes, but they were given no information about the training procedure. They all had only the general knowledge that the study was to investigate biofeedback training of peripheral temperature. Prior to the baseline, all subjects heard the same taped instructions, which outlined the hook-up and the baseline monitoring procedures. Participants were assured that there would be nothing painful or harmful about the experiment and they were encouraged to get comfortable. The verbatim instructions are presented in Appendices B and C.

The instructions were interrupted while the electrodes and thermistors were attached. The diagram in Appendix D depicts the electrode and thermistor placement. Subjects were instructed to avoid unnecessary movements and irregular breathing. For the baseline low volume music was played while subjects were monitored for eight 90-second trials separated by 30-second intertrial intervals. Right finger temperature and EMG were monitored continuously throughout the trials and at the end of each trial the apparatus was switched to get an instantaneous temperature reading from the left finger. By the end of the 30-second interval, the apparatus was reset for the right hand and monitoring resumed. Subjects were unaware of these temporal divisions.

From their perspective, they were being monitored continuously for 16 minutes.

After the baseline, instructions administered to controls and to feedback subjects were different. For both groups, there was equal emphasis on relaxation. The feedback group was given training instructions and the controls were told that they should continue to relax, while they were monitored for another 24 minutes without music. The biofeedback instructions urged subjects to take a casual approach to the training, that it was easy to do, as past training indicated, and just to remain relaxed and not to try too hard. They were assured that nobody was judging their performance and so they should take an exploratory approach. They were provided 2 sources of feedback, a tone that varied in pitch with temperature changes, and a continuously changing digital display of the absolute temperature from their right finger. The relationship between the feedback and their temperature was explained and demonstrated, and subjects were told to use the feedback to warm their finger. The training phase was divided into twelve 90-second training trials separated by 30-second rest intervals during which feedback stopped and subjects stopped trying to warm. The control group was monitored for the same period of time, and their records scored according to the same temporal divisions.

Just prior to training, biofeedback subjects indicated on a 4-point Likert-type scale, their expectations of

warming (Appendix E). After all monitoring for the session was completed, biofeedback subjects were asked to describe what they did during training to try to warm their finger. This questioning was left open-ended so as to get as much information as possible about what factors are important to successful training. Finally, room temperature was recorded on the Autogen 2000, at the beginning and the end of the session, from a temperature probe on the wall. The entire procedure was the same for both sessions although on the second day, instructions were slightly abbreviated.

The Autogen 5600 Data Acquisition Centre provided recordings of average right hand temperature and EMG for each 90-second trial as well as the instantaneous temperature readings at the end of each trial. In addition to this, the experimenter manually recorded readings, from the digital display, at the beginning of each trial (0 seconds), after 30 seconds and after 60 seconds. During the rest interval, the Autogen 2000 was switched to channel B to get an instantaneous reading (manually recorded) of the temperature from the left hand.

Results

General Description of Groups

Subjects were categorized according to their membership in the feedback/control and child/adult groups. Initially all data were analyzed by BMDP 9D (1979 version). Means and variances were obtained for all variables for each group and one-way analyses of variance tested quality of group means. Control and feedback groups were well matched on age. Mean ages for the child groups were 11.45 (control) and 11.42 (feedback) years. The mean age for adult feedback subjects was 19.8 years and for adult controls 20.6 years.

Analysing the credibility ratings, children and adult feedback subjects reported similar expectations of warming on both days. Means for the groups were equal on the first day (2.5) and were 2 and 2.5 for children and adults respectively on the second day. Correlations between credibility ratings and average temperature change during training were calculated for each session. Average temperature change was calculated by taking the change for each trial (first reading subtracted from last reading) and averaging that for each block of four trials. Temperature change during training was the average of the 3 training blocks. Correlations for both sessions are in the expected direction. For day one $r = -.50$ ($p < .05$) and for day two $r = -.37$ ($p > .05$, n.s.). The negative correlations suggest that there was a tendency for subjects who reported lower

expectations of warming (4 indicated "not at all") to manifest less warming or more cooling than those indicating a greater expectation of warming.

Room temperature (recorded at the beginning and end of each session) increased over each session but this change was consistent across subjects, typically increasing 1.5° to 2.0° F. Average room temperature per session was calculated (mean of the two readings) and analysed for group differences. The means and standard deviations and the analysis of variance summary table are presented in Table 1. While the differences between groups are not statistically significant, they are striking enough to warrant further investigation. This variable will be examined again in relation to analysis of finger temperature measures.

Initial Right Hand Temperature

Table 2 contains the means and standard deviations for the first right hand temperature readings obtained during each session. Although subjects were randomly assigned to training groups examination of these means indicates that the adult biofeedback group initially had colder finger temperatures than the other groups. While this difference was not statistically significant, it warranted further examination. Since room temperature also tended to be lower for this group during the first session correlations between room temperature and initial finger temperature were calculated for all subjects for each session.

Table 1

Average Room Temperature for Age x Training Group

	<u>Session One</u>		<u>Session Two</u>	
	<u>$\bar{X}$</u>	<u>s.d</u>	<u>$\bar{X}$</u>	<u>s.d</u>
Child control	75.05	2.43	75.10	2.13
Adult control	74.06	2.18	74.59	2.62
Child Feedback	75.09	2.30	74.90	1.70
Adult Feedback	73.25	2.35	74.41	2.00

Analysis of Variance Summary Table for Room Temperature

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability</u>
Age	14.63062	1	14.63062	1.63	.2125
Training Group	1.32250	1	1.32250	.15	.7042
Age x Training Group	.68062	1	.68062	.08	.7852
Error	251.66375	28	8.98799		
Session	2.40250	1	2.40250	2.57	.1200
Session x Age	3.33063	1	3.33063	3.56	.0694
Session x Training Group	.16000	1	.16000	.17	.6822
Session x Age x Training Group	.76563	1	.76563	.82	.3731
Error	26.16124	28	.93433		

Table 2
Initial Right-Hand Reading for
Age x Training Group x Session

	<u>Session One</u>		<u>Session Two</u>	
	<u>$\bar{X}$</u>	<u>s.d.</u>	<u>$\bar{X}$</u>	<u>s.d.</u>
Child control	91.43	3.44	92.62	2.54
Adult control	91.21	9.17	93.08	5.84
Child feedback	94.01	3.14	92.09	6.16
Adult feedback	85.34	9.85	92.24	8.86
	$F(3,28) = 2.119$ $p = .12$		$F(3,28) = .045$ $p = .98$	

In light of evidence in the literature, that ambient room temperature influences peripheral skin temperature (e.g., King & Montgomery, 1980) the low correlations obtained between room temperature and initial finger temperature were somewhat surprising. For session one $r = .21$ and for session two $r = .16$. Room temperature accounts for very little of the variance in initial finger temperature. There is no simple explanation for the difference other than sampling fluctuations. However, there are theoretical reasons to expect that initial temperature may influence temperature changes. Therefore, this variable was statistically controlled in appropriate analysis of covariance on average block temperature change.

Right Hand Temperature: Block Change

Block change was calculated as the average trial change (last reading minus first reading in each trial) for each block of four trials. After initial inspection of the data, it was decided to exclude the last block from the analysis. This consisted of the 4 recovery trials which appeared to add no information to the analysis. Since there was obviously no trained warming effect, the examination of a recovery period was redundant. This left 5 blocks (2 baseline and 3 training) in the analysis.

Analysis of average temperature change within blocks was

done initially with no covariates. A $2 \times 2 \times 5$ split plot analysis of variance on average block change was done for each session. Age group (child/adult) and training group (control/feedback) were between subject factors and block (1-5) was the within subject factor. The cell means and standard deviations are presented in Table 3. The analysis of variance results are presented in Tables 4 and 5. For both sessions, the age group and the block main effects are significant.

Since the compound symmetry assumption was violated, the block effect (repeated factor) and any interactions involving block must be tested against the conservative Geisser Greenhouse critical F (Kirk, 1968). The block main effect was significant at the $\alpha = .01$ level, for both sessions but none of the interactions were significant, even by the more liberal conventional criterion. The age group main effect was significant in both sessions ($p = .016$ for session one and $p = .011$ for session two). However, neither the training group nor the age group by training group interactions was significant.

In an attempt to equate statistically the groups on their initial temperature, subjects first right-hand reading in each session was entered as a covariate in an analysis of covariance, with the same factors as the above analysis. The adjusted cell means are presented in Table 6. Tables 7 and 8 contain analysis of variance summary tables. Comparing these results to those in Tables 4 and 5, it is evident that controlling for variance due to initial temperature reduces the tail probability for the

Table 3
Average Block Change For
Age x Training Group x Session

Session One

	<u>Block 1</u>		<u>Block 2</u>		<u>Block 3</u>		<u>Block 4</u>		<u>Block 5</u>	
	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>
Child control	.528	.39	.016	.20	.389	.138	.013	.27	-.101	.18
Adult control	.212	.14	-.08	.20	-.003	.30	-.017	.21	-.036	.17
Child feed-back	.311	.34	-.06	.22	-.038	.23	.037	.15	.065	.17
Adult feed-back	.281	.57	-.123	.28	-.113	.226	-.096	.14	-.042	.26

Session Two

Child control	.408	.41	-.025	.22	.155	.28	-.053	.32	.099	.26
Adult control	.185	.18	.083	.38	-.049	.36	-.096	.21	-.183	.27
Child feed-back	.563	.97	-.043	.11	.158	.19	.016	.29	.025	.22
Adult feed-back	.057	.15	-.025	.16	-.126	.33	-.177	.19	-.292	.24

Table 4

Analysis of Variance Summary Table

Average Block Change

Session One

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability by conventional criterion</u>
Age	.54435	1	.54435	6.60*	.0158
Training	.19130	1	.19130	2.32	.1388
Age x Training Group	.04979	1	.04979	.60	.4435
Error	2.30775	28	.08242		
Block	3.28840	4	.82210	12.88*GG	.0000
Block x Age	.22048	4	.05512	86	.4883
Block x Training Group	.49716	4	.12429	1.95	.1075
Block x Age x Training Group	.38536	4	.09634	1.51	.2043
Error	7.14925	112	.06383		

*GG: $p < .01$ by Geisser-Greenhouse criterion.

Table 5
 Analysis of Variance Summary Table
 Average Block Change

Session Two					
<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability by conventional criterion</u>
Age	1.19111	1	1.19111	7.39*	.0111
Training Group	.01139	1	.01139	.07	.7923
Age x Training Group	.27931	1	.27931	1.73	.1987
Error	4.51347	28	.16120		
Block	3.68062	4	.92016	9.14*GG	.0000
Block x Age	.80822	4	.20205	2.01	.0982
Block x Training Group	.03353	4	.00838	.08	.9874
Block x Age x Training Group	.06314	4	.01578	.16	.9595
Error	11.27080	112	.10063		

*GG: $p < .01$ by Geisser-Greenhouse Criterion

Table 6

Average Block Change

Age x Training Group x Session

(Cell Means Adjusted for Initial Temperature)

Session One

	<u>Block 1</u>	<u>Block 2</u>	<u>Block 3</u>	<u>Block 4</u>	<u>Block 5</u>
Child control	.533	.021	.386	.019	-.095
Adult control	.216	-.076	.002	-.013	-.032
Child feed-back	.331	-.040	-.018	.057	.085
Adult feed-back	.251	-.153	-.142	-.125	-.071

Session Two

Child control	.409	-.024	.156	-.052	-.098
Adult control	.192	.090	-.043	-.089	-.176
Child feed-back	.557	-.049	.153	.010	.020
Adult feed-back	.054	-.028	-.129	-.179	-.294

Table 7

Analysis of Variance Summary Table
Average Block Change - With Covariate

Session One						
Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Tail Probability by conventional criterion	Beta Estimates
Age	.72580	1	.72580	9.44*	.0048	
Training Group	.24285	1	.24285	3.16	.0869	
Age x Training Group	.00455	1	.00455	.06	.8097	
Covar(initial temp.)	.23083	1	.23083	3.00	.0946	-.00570
Error	2.07692	27	.07692			
Block	3.28840	4	.82210	12.88*GG	.0000	
Block x Age	.22048	4	.05512	.86	.4883	
Block x Training Group	.49716	4	.12429	1.95	.1075	
Block x Age x Training Group	.38536	4	.09634	1.51	.2043	
Error	7.14925	112	.06383			

*GG: $p < .01$ by Geisser-Greenhouse criterion

Table 8

Analysis of Variance Summary Table
Average Block Change - With Covariate

Session Two						Tail Probability by conventional criterion	Beta Estimates
Source	Sum of Squares	Degrees of Freedom	Mean Square	F			
Age	1.13537	1	1.13537	8.11*		.0083	
Training Group	.02541	1	.02541	.18		.6734	
Age x Training Group	.28849	1	.28849	2.06		.1626	
Cova(initial temp.)	.73503	1	.73503	5.25		.0922	-.01157
Error	3.77845	27	.13994				
Block	3.68062	4	.92016	9.14*GG		.0000	
Block x Age	.80822	4	.20205	2.01		.0982	
Block x Training Group	.03353	4	.00838	.08		.9874	
Block x Age x Training Group	.06314	4	.01578	.16		.9595	
Error	11.27080	112	.10063				

*GG: $p < .01$ by Geisser-Greenhouse criterion.

between subject effects, although the results are the same. Age group and block effects remain statistically significant.

Tukey's ratios were calculated for comparisons among overall adjusted block means within the block main effect. The block means and the test results for each session are presented in Table 9. For both sessions, block one was significantly different ($p < .01$) from each of the other blocks, which were not significantly different from each other.

Although visual inspection and the previous analyses suggest no session effects, temperature change across sessions was analysed by calculating average temperature change (mean block change) in the baseline and training phases of each session and conducting a $2 \times 2 \times 2 \times 2$ (age group by training group by session by phase) analysis of variance. Data were broken down into phases so as not to exceed an appropriate number of levels of the repeated measures. Table 10 displays the results of this analysis. As expected no significant session effects were found. Any training effect would be evident in either a phase by training group interaction or in a phase by session by training group interaction. Table 10 indicates that the tail probabilities for these effects are .91 and .95 respectively.

Table 11 shows the results of the same analysis with initial temperature statistically controlled. While the same effects are significant, a noteworthy effect of the covariate adjustment is on the session by age group by training group

Table 9
 Tukey's Tests on Mean Change in
 Block with Covariate Adjustments

<u>Means</u>		<u>Differences</u>			
<u>Session One</u>		<u>$\bar{X}_2$</u>	<u>$\bar{X}_3$</u>	<u>$\bar{X}_4$</u>	<u>$\bar{X}_5$</u>
$\bar{X}_1 = .33286$		.3947*	.2760*	.3485*	.3611*
$\bar{X}_2 = -.0618$			-.1187	-.0462	-.0336
$\bar{X}_3 = .0659$				.0725	.0851
$\bar{X}_4 = -.0156$					-.0438
$\bar{X}_5 = -.0282$					
*p<.01					
<u>Session Two</u>					
$\bar{X}_1 = .3032$		.3509*	.2688*	.3806*	.4403*
$\bar{X}_2 = -.0027$			-.0371	-.0747	.1344
$\bar{X}_3 = .0344$				.1118	.1715
$\bar{X}_4 = -.0774$					.0597
$\bar{X}_5 = -.1371$					
*p<.01					

Table 10
 Analysis of Variance Summary Table
 Average Block Change Collapsed into Phases
 (Age x Training Group x Session x Phase)

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Tail Probability
Age	.65958	1	.65958	9.35*	.0049
Training Group	.06052	1	.06052	.86	.3622
Age x Training Group	.01447	1	.01447	.21	.6541
Error	1.97518	28	.07054		
Session	.01977	1	.01977	.48	.4940
Session x Age	.02050	1	.02050	.50	.4862
Session x Training Group	.02042	1	.02042	.50	.4871
Session x Age x Training Group	.13063	1	.13063	3.17	.0857
Error	1.15283	28	.04117		
Phase	.93289	1	.93289	24.23*	.0000
Phase x Age	.00087	1	.00087	.02	.8817
Phase x Training Group	.00018	1	.00018	.00	.9460
Phase x Age x Training Group	.00662	1	.00662	.17	.6815
Error	1.07815	28	.03851		
Session x Phase	.05004	1	.05004	1.17	.2882
Session x Phase x Age	.00558	1	.00558	.13	.7205
Session x Phase x Training Group	.00062	1	.00062	.01	.9050
Session x Phase x Age x Training Group	.01599	1	.01599	.37	.5454
Error	1.19554	28	.04270		

Table 11

Analysis of Variance Summary Table

Average Block Change Collapsed into Phases

With Covariate Adjustment

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Tail Probability	Beta Estimates
Age	.80135	1	.80135	12.76*	.0014	
Training Group	.09062	1	.09062	1.44	.2400	
Age x Training Group	.04853	1	.04853	.77	.3870	
Covar(initial temp.)	.28019	1	.28019	4.46*	.0440	-.00849
Error	1.69499	27	.06278			
Session	.00128	1	.00128	.04	.8431	
Session x Age	.00440	1	.00440	.14	.7138	
Session x Training Group	.03362	1	.03362	1.05	.3148	
Session x Age x Training Group	.02818	1	.02818	.88	.3567	
Covar(initial temp.)	.28761	1	.28761	8.98*	.0058	-.01584
Error	.86522	27				
Phase	.93289	1	.93289	24.23*	.0000	
Phase x Age	.00087	1	.00087	.02	.8817	
Phase x Training Group	.00018	1	.00018	.00	.9460	
Phase x Age x Training Group	.00662	1	.00662	.17	.6815	
Error	1.07815	28	.03851			
Session x Phase	.05004	1	.05004	1.17	.2882	
Session x Phase x Age	.00558	1	.00558	.13	.7205	
Session x Phase x Training Group	.00062	1	.00062	.01	.9050	
Session x Phase x Age x Training Group	.01599	1	.01599	.37	.5454	
Error	1.19554	28	.04270			

interaction which approaches significance in the first analysis ($p=.086$) but after the covariate adjustment, this effect disappears ($p=.36$). In both analyses age group ($p<.001$) and phase ($p<.001$) are powerful main effects. There is a significant effect of the covariate both between groups ($p<.05$) and across sessions ($p<.01$).

EMG

While no training effect is evident from the analyses of average block temperature change, visual inspection of the EMG data suggested a possible training effect on that measure. EMG in each block was calculated by averaging the mean absolute EMG readings of the 4 trials in each block. Since the distribution of the EMG data was highly positively skewed and the group variances were very heterogeneous, log transformations were performed for the analysis. Cell means and standard deviations of the raw measures and the log-transformed data for the average EMG per block are presented in Table 12. Figure 1 illustrates average block EMG for feedback and control subjects for each session.

Results of $2 \times 2 \times 5$ analysis of variance tests (age group by training group by block) on block average EMG for each session are found in Tables 13 and 14. For session one the only near significant effect is the block by training group interaction. Using the conventional F test, $p = .013$. However, because of violation of the compound symmetry assumption the Geisser Greenhouse test is more appropriate. The tail probability for the conservative test with $F=3.3$ is somewhere

Table 12a

Mean EMG Scores:

Age x Training Group x Block x Session

Session One

	<u>Block 1</u>		<u>Block 2</u>		<u>Block 3</u>		<u>Block 4</u>		<u>Block 5</u>	
	<u>$\bar{X}$</u>	<u>s.d</u>	<u>$\bar{X}$</u>	<u>s.d</u>	<u>$\bar{X}$</u>	<u>s.d</u>	<u>$\bar{X}$</u>	<u>s.d</u>	<u>$\bar{X}$</u>	<u>s.d</u>
Child control	3.763	2.01	3.008	2.12	3.549	2.15	3.010	2.16	3.251	2.38
Adult control	1.881	.98	3.766	3.85	2.065	1.57	3.562	3.64	1.991	1.09
Child Feed-back	2.325	.97	2.289	.81	6.216	9.66	7.896	14.90	8.091	15.32
Adult Feed-back	3.255	1.60	1.816	.22	6.067	3.96	5.107	5.32	4.46	3.76

Session Two

Child control	3.210	3.47	3.675	3.55	3.850	2.94	2.717	1.46	3.058	1.67
Adult control	2.594	2.12	2.153	1.27	3.003	2.42	3.108	2.91	3.367	4.62
Child Feed-back	2.173	1.21	2.565	1.65	3.421	2.86	2.488	1.34	3.120	1.62
Adult Feed-back	2.211	1.11	2.135	1.36	4.950	4.52	3.290	1.17	4.235	3.61

Table 12b

Mean Log Transformed EMG

Age x Training Group x Block x Session

Session One

	<u>Block 1</u>		<u>Block 2</u>		<u>Block 3</u>		<u>Block 4</u>		<u>Block 5</u>	
	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>	<u>X</u>	<u>s.d</u>
Child control	.510	.27	.400	.27	.466	.30	.393	.28	.420	.30
Adult control	.235	.19	.422	.36	.251	.22	.395	.37	.259	.18
Child Feed-back	.337	.17	.333	.17	.516	.45	.533	.50	.540	.50
Adult Feed-back	.467	.21	.256	.05	.689	.32	.552	.37	.535	.32

Session Two

Child control	.384	.30	.418	.36	.492	.29	.386	.21	.441	.20
Adult control	.331	.26	.279	.22	.393	.27	.378	.31	.350	.34
Child Feed-back	.281	.21	.338	.26	.440	.28	.342	.23	.440	.24
Adult Feed-back	.311	.17	.280	.20	.567	.34	.495	.15	.526	.29

FIGURE 1

LOG TRANSFORMED EMG SESSION ONE

SESSION TWO

Table 13

Analysis of Variance Summary Table
Average EMG in Block (Log Transformed)

Source	Sum of Squares	Degree of Freedom	Mean Square	F	Tail Probability by Conventional Criterion
Age	.06068	1	.06068	.22	.6440
Training Group	.40789	1	.40789	1.47	.2359
Age x Training Group	.29984	1	.29984	1.08	
Error	7.78403	28	.27800		
Block	.37613	4	.09403	1.83	.1271
Block x Age	.04813	4	.01203	.23	.9182
Block x Training Group	.67726	4	.16932	3.30*GG	.0134
Block x Age x Training Group	.40016	4	.10004	1.95	.1067
Error	5.73958	112	.05125		

*GG: p between .10 and .05 by Geisser-Greenhouse criterion.

Table 14
 Analysis of Variance Summary Table
 Average EMG in Block (Log Transformed)

Session Two					Tail Probability by Conventional Criterion
Source	Sum of Squares	Degree of Freedom	Mean Square	F	
Age	.00134	1	.00134	.01	.9403
Training Group	.01190	1	.01190	.05	.8230
Age x Training Group	.20837	1	.20837	.89	.3529
Error	6.53750	28	.23348		
Block	.54134	4	.13534	4.90*GG	.0011
Block x Age	.12038	4	.03009	1.09	.3654
Block x Training Group	.12943	4	.03236	1.17	.3274
Block x Age x Training Group	.03333	4	.00833	.30	.8763
Error	3.09453	112	.02763		

*GG: $p < .05$ by Geisser Greenhouse criterion

between .05 and .10. For session two, this block by training group interaction does not even approach significance. The main effect for block is the only significant effect by the liberal or the conservative criterion ($p < .05$ for the Geisser-Greenhouse test).

To determine the effect of EMG across both sessions without exceeding an appropriate number of levels of the repeated measures factors in the analysis, the EMG data were collapsed into the average for each of the baseline and the training phases for each session. The average log-transformed EMG in each phase was analysed in a $2 \times 2 \times 2 \times 2$ split plot analysis of variance (age group by training group by session by phase). As Table 15 shows, the main effect for phase was significant, as was the phase by group interaction. For both sessions, change in muscle activity from baseline to training was different for feedback subjects than for controls. No session effects even approached significance.

Even more interesting than the effects on EMG per se is the influence of the EMG on the temperature changes so the analysis of the EMG data alone was not pursued further. Of primary concern was the question of whether the EMG variations were masking a training group effect on temperature.

Analysis of covariance tests on average block temperature change were done using the log-transformed EMG readings as the covariate. Results of the age group by training group by block analyses, are found in Tables 16 and 17. The adjusted cell means are presented in Table 18. Removing the variance in temperature

Table 15
 Analysis of Variance Summary Table -
 Average EMG in Phase (Log Transformed)
 (Age x Training Group x Session x Phase)

<u>Source</u>	<u>Sum of Squares</u>	<u>Degree of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability</u>
Age	.02414	1	.02414	.15	.7031
Training Group	.05524	1	.05524	.34	.5649
Age x Training Group	.18386	1	.18386	1.13	.2970
Error	4.55846	28	.16280		
Session	.03571	1	.03571	1.46	.2363
Session x Age	.00564	1	.00564	.23	.6342
Session x Training Group	.04002	1	.04002	1.64	.2106
Session x Age x Training Group	.00265	1	.00265	.11	.7440
Error	.68250	28	.02438		
Phase	.32529	1	.32529	6.39*	.0174
Phase x Age	.02085	1	.02085	.41	.5273
Phase x Training Group	.24696	1	.24696	4.85*	.0360
Phase x Age x Training Group	.01024	1	.01024	.20	.6572
Error	1.42474	28	.05088		
Session x Phase	.00217	1	.00217	.08	.7816
Session x Phase x Age	.00876	1	.00876	.32	.5782
Session x Phase x Training Group	.03382	1	.03382	1.22	.2785
Session x Phase x Age x Training Group	.00289	1	.00289	.10	.7491
Error	.77531	28	.02769		

Table 16
 Analysis of Variance Summary Table
 Average Temperature Change in Block With
 EMG as Covariate
 Session One

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Total Probability by Conventional Criterion</u>	<u>Beta Estimates</u>
Age	.54556	1	.54556	6.39*	.0177	
Training Group	.17390	1	.17390	2.04	.1651	
Age x Training Group	.05154	1	.05154	.60	.4440	
Covar(EMG)	.00175	1	.00175	.02	.8872	-.01500
Error	2.30600	27	.08541			
Block	3.30354	4	.82589	12.85*GG	.0000	
Block x Age	.22259	4	.05565	.87	.4868	
Block x Training Group	.50756	4	.12689	1.97	.1032	
Block x Age x Training Group	.34353	4	.08588	1.34	.2608	
Covar(EMG)	.01735	1	.01735	.27	.6044	.05498
Error	7.13190	111	.06425			

*GG: $p < .01$ by Geisser Greenhouse criterion

Table 17

Analysis of Variance Summary Table
Average Temperature Change in Block with
EMG as Covariate
Session Two

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Tail Probability by Conventional Criterion	Beta Estimates
Age	1.19404	1	1.19404	7.16*	.0125	
Training Group	.01047	1	.01047	.06	.8041	
Age x Training Group	.25243	1	.25243	1.51	.2292	
Covar(EMG)	.01031	1	.01031	.06	.8055	-.03971
Error	4.50316	27	.16678			
Block	3.41764	4	.85441	8.43*GG	.0000	
Block x Age	.78071	4	.19518	1.93	.1111	
Block x Training Group	.03622	4	.00905	.09	.9856	
Block x Age x Training Group	.06593	4	.01648	.16	.9568	
Covar(EMG)	.02164	1	.02164	.21	.6450	-.08361
Error	11.24916	111	.10134			

*GG: $p < .01$ by Geisser Greenhouse criterion

Table 18

Average Temperature Change in Block

Adjusted for EMG

Session One

<u>Block</u>	<u>Child Control</u>	<u>Child Feedback</u>	<u>Adult Control</u>	<u>Adult Feedback</u>
1	.52615	.31269	.21593	.27981
2	.01613	-.05788	-.07994	-.11980
3	.37983	-.03989	.00094	-.11767
4	.01408	.03445	-.01626	-.09810
5	-.10052	.06269	-.03236	-.04372

Session Two

1	.40723	.55620	.18162	.05230
2	-.02360	-.04675	.07605	-.03204
3	.16047	.16082	-.04940	-.11574
4	-.05388	.01291	-.09658	-.17062
5	-.09627	.02801	-.18572	-.28376

change due to EMG does not change the results. There is still no evidence of a training effect.

Phase Shift

Figures 2 and 3 illustrate absolute right hand temperature readings for each session, broken down by age group.

While the change in temperature across blocks and phases is evident in the average blocks and average phase analyses, an effect which is obvious visually, yet is not tested in any of the previous analyses is the shift in temperature from the end of the baseline phase to the beginning of the training phase.

This phase shift was isolated by subtracting reading 8 from reading 9 and a 2 (age group) by 2 (training group) by 2 session analysis of variance was done. Results of this analysis, presented in Table 19, indicate that only the main effect for age group is significant ($F=7.9$, $p<.01$). This reveals that overall, children showed a larger drop in temperature than adults between baseline and training phases.

Response Specificity: Right-Left Correlations

Past investigators have claimed that with training, they have elicited a response which is fairly specific to the training site. Since the present study produced no evidence of biofeedback-induced warming, analysis of response specificity with trained warming was not possible. However, with the data available it seemed that examining right-left correlations as a function of age group and training might be useful. Within subject correlations, between right and left readings were

FIGURE 2

TEMPERATURE ACROSS TRIALS
SESSION ONE

FIGURE 3

Table 19

Analysis of Variance Summary Table
 Phase Shift : Mean Temperature
 Change Between Baseline and Training Phases

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability</u>
Age	16.98469	1	16.98469	7.90*	.0089
Training Group	4.84550	1	4.84550	2.25	.1444
Age x Training Group	2.51619	1	2.51619	1.17	.2884
Error	60.17029	28	2.14894		
Session	.00001	1	.00001	.00	.9975
Session x Age	.55689	1	.55689	.40	.5306
Session x Training Group	.85331	1	.85331	.62	.4384
Session x Age x Training Group	.24379	1	.24379	.18	.6776
Error	38.66414	28	1.38086		

calculated for baseline and training phases of each session (using the Shazam computer program). The right-left correlation coefficients were analysed in a 2 (age group) by 2 (training group) by 2 (session) by 2 (phase) analysis of variance. The results, shown in Table 20 indicated that no significant effects were obtained. As expected, overall mean correlation between right and left readings was high and statistically significant ($\bar{r}=.86$, $p<.01$).

Initially, the "near significant" four-way interaction between session, phase, age group and training group seemed exciting, apparently indicating development of some response specificity among the adult biofeedback subjects during training of session two. However, the large standard deviation for this cell casts some suspicion on the effect and careful scrutiny of the data proved the suspicion justified. The mean correlation for adult feedback subjects during this phase was artificially lowered by one subject who had a large negative correlation for training of session 2 ($r = -.65$). If this same subject had not had such low initial temperature (right hand 70.97 and left, slightly warmer at 71.13) this might still be a significant finding since this subject also was one of the few who showed any warming tendency. However, the low initial temperature allowed for a greater range in warming, so by the end of training right temperature was 72.18 and left was just slightly cooler at 72.0. Given the cooler initial temperature and the

Table 20
Analysis of Variance Summary Table
Right-Left Correlations
(Age x Training Group x Phase x Session)

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability</u>
Age	.00008	1	.00008	.00	.9677
Training Group	.10626	1	.10626	2.36	.1353
Age x Training Group	.01133	1	.01133	.25	.6196
Error	1.25820	28	.04494		
Session	.00915	1	.00915	.22	.6403
Session x Age	.01221	1	.01221	.30	.5895
Session x Training Group	.02634	1	.02634	.64	.4295
Session x Age x Training Group	.00605	1	.00605	.15	.7037
Error	1.14733	28	.04098		
Phase	.01051	1	.01051	.25	.6190
Phase x Age	.00567	1	.00567	.14	.7146
Phase x Training Group	.00008	1	.00008	.00	.9664
Phase x Age x Training Group	.01333	1	.01333	.32	.5758
Error	1.16392	28	.04157		
Session x Phase	.03740	1	.03740	.79	.3811
Session x Phase x Age	.13624	1	.13624	2.88	.1005
Session x Phase x Training Group	.05064	1	.05064	1.07	.3093
Session x Phase x Age x Training Group	.17925	1	.17925	3.79	.0615
Error	1.32265	28	.04724		

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greater variance in temperature this negative correlation is misleading and its interpretation is unclear. Thus, the data provide scant evidence for specificity of effect.

Sex

Although there is little evidence in the literature for sex differences in temperature feedback training, all data were broken down by sex in the preliminary analyses. In no case did the results warrant any further examination of sex differences. Males and females showed highly similar temperature and EMG responses in all four groups. However, the obvious reservation in considering these data concerns the small sample size ($n=4$) when subjects are broken down on all variables (age group, training group, and sex). Thus, while the results of the present study offer no evidence of sex differences, the small sample size makes generalization unwise.

Verbal Reports

Subjects reported a wide variety of strategies to attempt to increase finger temperature including imagery, direct commands to the hand and/or to the feedback, relaxation and doing nothing (ignoring it). However, the failure to find a reliable warming effect rendered meaningless any attempt to explore the efficacy of the various strategies.

Comparative Analysis: Failure to Replicate?

The results of the present study suggest no warming effect associated with feedback training over 2 sessions. This

is inconsistent with many of the studies reviewed however, it is not unexpected since many of the procedural differences between previous studies and the present one were intended to challenge the efficacy of the feedback training when certain confounding variables were controlled. Further analysis of data collected during the present study suggest that much of the discrepancy between this study and many of those reviewed may be a result of confounding adaptation effects and training effects.

To demonstrate how temperature fluctuations resulting from adaptation and relaxation effects may have been confounded with training effects in studies using shorter baselines, the performance measure (average temperature change within each trial) used by Hunter et al. (1976) was calculated for both sessions, using temporally comparable readings in the present study. Since Hunter and her colleagues' entire session consisted of 2-minutes of baseline monitoring followed by three 3-minute training trials, all of the readings determining the "mean daily performance" (MDP) measure were obtained from the baseline period of the present study.

An age group x training group x session analysis of variance on "MDP" revealed a significant age group x training group x session interaction ($p < .05$) and significant overall performance ("MDP" collapsed across groups and sessions, $p < .001$). These results are presented in Table 21. Looking at children only, mean overall performance for the 2 sessions

Table 21
 Analysis of Variance Summary Tables
 "Mean Daily Performance" - Measures

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Tail Probability</u>
Overall Performance	3.89240	1	3.89240	14.86*	.0006
Age	.91282	1	.91282	3.49	.0724
Training Group	.52623	1	.52623	2.01	.1673
Age x Training Group	.01995	1	.01995	.08	.7846
Error	7.33203	28	.26186		
Session	.01332	1	.01332	.08	.7835
Session x Age	.01834	1	.01834	.11	.7472
Session x Training Group	.02019	1	.01019	.12	.7353
Session x Age x Training Group	.73316	1	.73316	4.24*	.0490
Error	4.84725	28	.17312		

(.36) was similar in magnitude to that reported by Hunter et al. for 5 sessions (.38). An interesting result of this analysis is the main effect for age group which approached significance ($p=.07$). Although this is not significant at the conventional $\alpha=.05$ level, it suggests at least, that not only is the baseline effect a powerful one that needs to be carefully controlled in biofeedback training but that it could vary across different subject samples.

Subsequent to the overall analysis of variance on the "MDP" measure, Tukey's ratio's were calculated to test for differences between group means within the age group x training group x session effect. These results are presented in Table 22.

Comparing training groups within each age group during session one revealed a significant difference between child control subjects and child biofeedback subjects ($q=2.98$, $p<.05$) but no difference between the two adult groups. Within training groups, child controls were significantly different from adult controls ($q=3.34$, $p<.05$) but the children and adult biofeedback subjects were not different. There were no significant differences between any of the groups during session two and within each group, there were no statistically significant differences between sessions one and two.

Table 22

"Mean Daily Performance"

Tukey's Multiple Comparison Tests

<u>Mean</u>	<u>Differences</u>		
	<u>Child Control</u>	<u>Adult Feedback</u>	<u>Adult Control</u>
<u>Session One</u>			
Child Feedback=.1354	.4663*	.0233	.0558
Child Control=.6017		.4896*	.5221*
Adult Feedback=.1121			.0325
Adult Control=.0796			
*p<.05			
<u>Session Two</u>			
Child Feedback=.3800	.0329	.3838	.0592
Child Control=.3471		.3509	.0263
Adult Feedback=--0038			.3246
Adult Control=.3208			

Discussion

Training Effects on Temperature

The results of this study indicated that under carefully controlled conditions, neither adults nor children demonstrated the ability to increase finger temperature with biofeedback training. Trained subjects showed no temperature increases relative to baseline measures and manifested change scores during baseline and training which were not significantly different from control subjects.

Analysis of average block change in temperature resulted in significant age group and block main effects. The training group main effect and interactions involving training group did not even approach significance. These results indicate that there are no training effects on temperature change and that while there are significant differences between children and adults, these differences are not related to the temperature feedback training. Although procedures for the two age groups were identical within each training condition, subjects within age groups were more similar than subjects within training groups.

Block Main Effect

Tukey's tests revealed the source of the block main effect for each session. The only significant differences were between the first block and each of the following blocks. This indicates that for all groups, finger temperature changes were larger during the first block than during later blocks,

which did not differ.

These results underline the importance of the adaptation or stabilization effect in temperature training. As will be argued in more detail below, it is possible that training effects reported in past studies represent confounding of stabilization and feedback, thus creating a training artifact.

No Session Effect

The results of the average block change analysis were the same for both sessions. Collapsing blocks into baseline and training phases and analysing temperature change as a function of age and training factors across both phase and session confirmed the observation of no session effects.

Failure to Replicate

Overall, these results are inconsistent with many of those found in the literature reporting successful training. Most of this discrepancy can be explained by procedural differences between the present study and others. This investigation was designed to eliminate some potentially confounding variables.

Adaptation Effect

One glaring confound evident in many past studies was the adaptation effect. The comparative analysis of Hunter et al. (1976) is directed to this issue. Replication of their "Mean daily performance" measure, using the temporally comparable readings from the present investigation revealed statistically significant "performance" measures similar to those reported by Hunter et al. (1976).

These results suggest that measures that are taken within the first 10 to 15 minutes of recording will reflect a temperature increase as a result of the adaptation effect. The results of this comparative analysis indicate that studies introducing an intervention without a 10 to 15 minute baseline are not capable of unequivocally demonstrating a training effect.

The finding of group differences indicates either that this adaptation effect varies across subjects of different ages or, that in analysing so sensitive and volatile a response as skin temperature, chance differences are not unlikely. This difference between children and adults on "MDP" or the adaptation effect is relevant when considered in relation to the reports of age differences in performance during temperature feedback training. Lynch et al. (1976) reported that they could not train adults, but subsequently successfully trained 4 children. Given their brief 3 minute baseline, their results are more likely indicative of differences in adaptation changes than of performance differences. Studies reporting successful training with children (e.g., Hunter et al., 1976; Lynch et al., 1976) typically used brief baseline periods. Thus the utility of their evidence of successful temperature training, or of children's superior performance, is highly questionable.

Analyses of the "MDP" measure in the present study indicated that the child control group had "better" performance than the other groups. This shows that group differences

in performance can be obtained even during the adaptation period. All groups were treated identically during the baseline period of session one and since assignment to training condition was random, there are no apparent explanations for this difference other than chance sampling fluctuations.

While the magnitude of these "MDP" measures and the magnitude of the differences between groups during session one seem small, they are similar to the differences reported by Hunter et al. (1976) between contingently (overall performance $\approx 5^{\circ}\text{F}$) and noncontingently ($.25^{\circ}\text{F}$) reinforced subjects. The idea that such statistical significance may be obtained independently of training (perhaps by chance) is supported by Hunter et al.'s report of an unpredicted significantly better overall performance for learning disabled than for normal children..

Hunter and her colleagues also analysed change in performance across 5 sessions. In the present analysis, this effect cannot be replicated; however, the data from the two sessions suggest that Hunter et al. were detecting a baseline effect which changed across days. While this function changed differentially across days in their 2 training groups, other methodological problems could account for such results.

While the number of reinforcements for the noncontingently reinforced group was yoked to the consistently reinforced group, the noncontingent application implies that the pattern is

different. Increasing finger temperature appears to be the prevalent response for the first 10 minutes of monitoring. It could be argued that those who are being reinforced consistently during this time would feel pleased with their success and would enter the period of reduced reinforcement (after adaptation) with a confident relaxed attitude reflected in maintenance of the warmer peripheral temperatures. Conversely, those who are reinforced noncontingently or randomly, although receiving the same number of reinforcements do not have the same experience of overwhelming success initially and consequently feelings of disappointment or frustration may eliminate the adaptation warming effect. Therefore, this group would manifest more vasoconstriction or finger cooling.

Inadequate baseline recording is a methodological problem which cannot be dismissed by a demonstration of differential responding in controls and feedback subjects. A good baseline measure of at least 12 minutes must be obtained to ensure that finger temperature has adapted prior to training. Hunter argued that this was unreasonable with their child subjects because of their "motor impersistence". The present investigation showed that it was quite feasible to have normal children between 10 and 12 years old sit still for monitoring for a much longer period.

In defense of their short baseline, Hunter et al. (1976) also suggested that the mean baseline temperatures of the

children in their study were the same as that of adults who had received lengthier baselines. The baseline differences between children and adults obtained in the present study weaken that argument.

Implications of Age Group Effects

The age effect in temperature responding is quite significant. Not only do children show significantly larger adaptation warming effects, as evident in the block change and "MDP" analyses, but their temperature drop from the end of baseline to the beginning of training (phase-shift) was significantly greater than that of adults. There is at present no obvious explanation for this age group effect.

One hypothesis to explain these data is that children are more reactive, i.e., they showed greater temperature changes in response to the experimental manipulations than adults. They warmed more over the baseline phase and cooled more during the instruction period between baseline and training phases. This hypothesis describes but does not explain the difference in reactivity.

An alternative explanation is that the greater increase over baseline was partially responsible for the greater drop subsequent to that. This explanation is based on the hypothesis that children were more relaxed about the experiment in general and so warmed more during baseline. Although there are no data to substantiate this idea, it has a theoretical basis in the subject sources. The children were

recruited through personal contact with their parents. They were young and had no academic or professional affiliation with the university or the experimenter except in some cases through their parents. The adult subjects were predominantly first year undergraduates at the university, enrolled in a psychology course. During the debriefing session, they frequently asked questions about psychology in general, and about psychology at Carleton in particular. All of the adults were pursuing a degree at the University and many of them were interested in doing it in psychology. An effect of these situational differences may have been that the children had a more relaxed attitude toward the experiment than the adults. The children had nothing either real or imagined to prove, or to lose.

The experimenter's own observations supported this hypothesis that the children embarked on the experiment with a different attitude -- they expressed curiosity and looked forward to it as they would a game. The adults expressed curiosity and anticipation also but these expressions tended not to be marked by the light quality evident in the children's attitudes. Based on these informal observations, it is conceivable that the children warmed more during baseline because they relaxed more easily, but then as expected showed some peripheral vasoconstriction while attending to the instructions and then warmed again during the next phase. The adults were not as

relaxed and did not warm as much during baseline. Consequently, the change (decrease) during instructions was less than that for the children. The EMG data does not reflect such a difference in relaxation or attitude between the children and the adults. However, while recording EMG from the back of the hand may have provided a good index of deliberate attempts at muscular mediation, it does not provide the best index of general relaxation. A better site for monitoring general relaxation is the forehead. Thus the fact that age differences were not found on EMG measures does not contradict a hypothesis of attitude differences between the children and adults. The only support for this speculation is informal experimenter observation and so this idea can be considered only a hypothesis at this time.

The suggestion, in the literature, that children perform better than adults during temperature feedback training because they are less skeptical of the training is not supported by this study. Neither group performed successfully, and children and adults respond differently, irrespective of training. The latter aspect of this theory, that children are less skeptical, is not supported by the credibility data. There were no differences between the children and the adults on their self-reported expectations of warming during training. It is worth considering the validity limitations of self report measures particularly given the indications of

different attitudes between children and adults. If the adults were more concerned about performing well and pleasing the experimenter, it is possible that they reported a higher expectation of success than they actually believed.

EMG

It has already been mentioned that the age group differences in temperature change could not be explained by differences in muscular activity. The age main effect was still highly significant after removing the variance due to EMG and the training effect was still nonsignificant. Analyzing EMG as a covariate accounted for little of the variability in temperature change.

However, examining the EMG data alone produced some interesting results. Contrary to expectation, there was no significant age effect in the EMG data. Children and adults did not manifest different amounts of muscular activity. The results of the age by training group by block analysis for each session indicated only a training group by block interaction which approached significance during session one. Collapsing average EMG data into baseline and training phases and conducting an age by training condition by session by phase analysis indicated, in the phase by training condition interaction that biofeedback subjects (children and adults) engaged in more muscular activity during training. Subjects had been explicitly instructed not to try to mediate the temperature changes by muscular changes and were encouraged to

relax for optimal performance. It is not clear, however, whether these higher EMG measures reflect a deliberate attempt to alter temperature by muscular mediation or a tendency of biofeedback subjects to become tense in the training situation. Both factors probably contribute to the effect with the former being the major influence. It has already been mentioned that EMG recordings from the hand are a better indication of muscular activity in the hand than of general relaxation.

In response to the open ended question "what were you doing during the training?", asked at the end of training, subjects did not indicate any awareness of having increased their muscle activity, deliberately or otherwise. However, the explicit experimental demands not to do so make it unlikely that subjects would volunteer that they had been tensing their muscles. Additionally, although elaborate efforts were made to make subjects as comfortable and relaxed as possible, it is possible that feedback subjects were more tense during training.

Interpretation of this effect would be aided by EMG readings monitored from several loci, including the untrained hand and the forehead. If the effect reflected a deliberate attempt to muscularly mediate the response, there would be a tendency for the increased EMG activity to be specific to the training site. Alternatively, if the effect

is predominantly the result of involuntary tension or performance anxiety, we could expect this to be reflected in a general EMG increase, particularly from the frontalis. This procedure still would provide only a rough indication of what is occurring but, combined with the verbal reports it might provide a basis for interpretation of the results. Whatever the explanation for the EMG effect, its presence necessarily affects interpretation of the training effects on temperature.

Muscle activity does have an influence on skin temperature (Plutchik, 1956) but the relationship is not as simple as most investigations have assumed (King & Montgomery, 1980). Controlling statistically the differences in muscle activity did not alter the finding of no training group differences in temperature change. However, this statistical control, although the only means available in the present investigation, is only a very crude method of attempting to equate groups on EMG. Because of the very complex interaction of variables affecting skin temperature, including skeletal muscular maneuvers, cognition and emotions (King & Montgomery, 1980), it is impossible to determine the full extent of the influence of the EMG effect on finger temperatures.

Taub and Emurian (1976) reported that hand temperature control demonstrated by two subjects was uncorrelated with EMG activity in the forearm. Their conclusion that the temperature control was independent of skeletal-muscular

maneuvers is poorly founded, and inconsistent with their observation that without EMG records from other parts of the body, the possibility of somatic mediation cannot be ruled out.

King and Montgomery (1980) criticize Hunter et al. (1976) for prematurely ruling out skeletal muscular maneuvers in their study by their oversimplified explanation that such maneuvers only cause decreases in skin temperature. Obviously, determination of the efficacy of peripheral temperature feedback training requires further investigation into the role of skeletal muscular variations.

Credibility

The results of the feedback subject's credibility ratings tend to support the hypothesis that trainees' expectations of warming are a relevant factor in temperature feedback training. Unfortunately, since there was no substantial evidence of trained finger temperature increases, it is difficult to determine exactly how important expectations are to successful training. While correlations were calculated on the data available, they were based on a small sample and so must be interpreted carefully. Concerning correlation measures, Snedecor and Cochran (1967) caution "sample correlations from a bivariable population are quite variable if n is small" (p. 175).

In spite of the statistical significance of the correlations, for the first session, only a small percentage of the

variance in performance is accounted for by expectation (25% for session one and 14% for session two). Nevertheless, these results indicate that there is a linear relationship sloping in the expected direction and this is significant for the first session. The absence of statistical significance for the second session is not surprising since the previous session may be presumed to influence subjects' original expectations of success. It was because of the different factors operating in the two sessions that the correlations were calculated for each session separately.

Finally, this significant correlation indicates only that there is an association between the expectation and the performance. We cannot conclude that the more optimistic expectations will enhance performance. Investigators, such as Taub (1977), have implied a causal relationship suggesting that a positive expectational set is important for successful training. The present study is consistent with that hypothesis but the data is still only correlational.

Room Temperature

From initial inspection of the data there arose some concern over possible differences between groups on room temperature. While these differences were not statistically significant it was important to examine this factor for an interpretation of group differences in skin temperature. The low correlations between the room temperature and subjects' initial finger temperatures appeared contrary to common

expectation. Finger temperature is reported to be influenced by environmental temperature (e.g., Plutchik, 1956).

However, it seems that within a truncated range, in this case the normal room temperature change (68° to 76° F) this relationship does not exist in between-subject analyses. It is possible that within subjects, this relationship is still evident, even within the truncated room temperature range. Without many room temperature paired with skin temperature data points on individual subjects, this cannot be determined. However, what the available data do indicate is that the room temperature differences within the restricted range of the present study, were not related to the subjects' initial temperatures.

Initial Finger Temperature

Of more direct relevance to temperature changes, than room temperatures, are group differences on initial temperature. Skin temperature is affected by several factors other than room temperature including exercise, muscle tension basal metabolic rate, food intake, sweating, change in room temperature gradient between the skin and the environment, amount of clothing worn, amount of air movements (King & Montgomery, 1980). The complex interaction of all these factors affecting skin temperature makes experimental control of them impossible under normal laboratory conditions. However, it is presumed that each of these factors as well as their interactions were constant throughout a session. Given this, combined with the procedure of randomly assigning subjects to training conditions, the importance of these

is minimal. While basal finger temperature differences between subjects could neither be explained nor experimentally controlled in the present investigation, the obvious procedure was statistical control in appropriate analysis of covariance.

Removing the variability due to initial temperature in the average block change analysis did not change the results. In spite of the significant covariate effect in session two ($p=.03$) and one which approached significance in session one ($p=.095$), there remained no training group effects which even approached significance and age remained highly significant.

The only effect of the covariate adjustment on the age by training group by session by phase average block change analysis, was to wipe out the age by training group interaction which had approached significance before the covariate adjustment. Overall, the apparent differences between subjects on basal temperatures made surprisingly little difference to the major results.

Right-Left Correlations

Results of the analysis on right-left correlations revealed no development of specificity as indicated by reduced correlations during the training phase for feedback subjects. The obvious point has already been made that assessment of response specificity with temperature training cannot be done without data from trainees who have succeeded in showing temperature control.

A Critical Evaluation of Taub and Emurian's "Peak Trial" Measure

A frequently cited study in the peripheral temperature training area is Taub and Emurian's (1976). In spite of some of the obvious problems with this study, including the confounds of instruction suggestions and monetary reward, it has been influential. A less obvious, and possibly more serious problem is their means of calculating temperature change. After examination of the data plotted for individual subjects in the present study, and then a closer look at Taub and Emurian's results, their dependent measures may be questionable.

Taub and Emurian report using a "relative measure of skin temperature, comparing change (from the initial stability point) on a training day with (the equivalent) change on the baseline day" (p. 214). Therefore an absolute change on a training day of -2°F for a subject trained to increase, would be reported as an increase of 1°F , if on the baseline day the subject had a change of -3°F . Although this manipulation of data alone is questionable, it might have been justifiable if it were not for their method of calculating the training day change. "If this change was monotonic in either the instructed or the wrong direction, the initial stability point was subtracted from the peak trial value. If it was nonmonotonic, the trial used in calculating the training day change was the peak trial in the

instructed direction (whether this was above or below the initial stability point)". Unfortunately, Taub and Emurian give no indication of either the absolute training day changes, or of the number of monotonic and nonmonotonic changes. In the present study, most of the changes, for feedback and control subjects, were nonmonotonic. Of a total of 16 sessions for each group, one of the child control sessions was monotonic, 3 of the adult control, 5 of the child biofeedback and 7 of the adult biofeedback.

Therefore, for the feedback subjects, 22 out of 32 sessions were nonmonotonic and by Taub and Emurian's criterion would have had change calculated as peak trial in instructed direction. After careful scrutiny of their criterion, it is apparent that a given temperature curve, fluctuating up and down, can have either an increase or a decrease effect calculated, depending on the instructed direction of change. Consequently, in cases where temperature fluctuates, which in the present study was the majority, this is clearly capitalising maximally on chance fluctuations. Even where the change is monotonic and "peak trial" value is compared to baseline, the bias is blatant. Peak trial is assumed to be the maximum performance trail. So whether a subject was monotonically increasing or monotonically decreasing, which point--beginning or end--was the "peak" would depend on the instructed direction of change.

This discussion of Taub and Emurian's dependent measure

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calculation is intended to illustrate how potent and sometimes how misleading data manipulation in the temperature feedback area can be. While transformations and calculations may be performed which result in an apparent temperature increase statistically, if all that this really means is slightly less cooling on a subsequent training day than on a baseline day, the relevance of this effect must be questioned. Given the various obscure data manipulations reported in the literature, it is likely that one could find other similar misrepresentations of training results. However, these are difficult to detect without examination of the raw data or at least data collected on similar measures. Nevertheless, new researchers should be wary of such misrepresentations.

Summary of Conclusions

It was found that in two lengthy, well-controlled sessions, neither children nor adults were able to warm their fingers. Children did not train better than adults although in general their finger temperature and observed behaviour suggested that they responded in a more relaxed way than did adults.

The results of the present investigation considered in conjunction with a careful scrutiny of the temperature feedback literature suggest that the efficacy of biofeedback training of peripheral temperature still requires substantiation. Miller's (1978) criticism that biofeedback studies

have not been careful enough at determining what type of learned effects were being produced, is still applicable today. Adaptation artifact, statistical artifact, and general relaxation effects are competing hypotheses for many of the prominent temperature training studies. The failure in the present study to replicate the effects reported in previous studies may be just a failure to replicate an artifact. Only further research will determine if this is the case.

Nonetheless, the possibility of successful training cannot be ruled out. Further studies are required to determine the efficacy of lengthier biofeedback training on finger warming. Monitoring muscle activity from more sites will provide further clues to the skeletal mediation and relaxation issues. It is expected that future research will produce more realistic indications of the potential of biofeedback training perhaps at the expense of the dynamic and exciting claims of success. This technique would offer far more in terms of therapeutic benefits when it is based more on sound scientific assessment and less on overzealous enthusiasm. Recognition of the limitations as well as identification of the optimum conditions for training temperature control--not artifact--are crucial for clinical success.

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APPENDIX A

APPARATUS AND HOOK-UP PROCEDURES

Autogenic System Incorporated (ASI) equipment was used for monitoring and providing feedback. The Autogen 2000B monitored temperature and provided the auditory feedback. One probe for each channel was utilized. The EMG from the right hand (trained hand for experimental subjects) was monitored by the Autogen 1700.

Temperature Probe Placement and Hook-up

The tip of the temperature probe or thermistor has a tiny semiconductor embedded in a small epoxy bead which acts as a temperature sensor when in contact with the skin. One of these probes was placed on the palmar surface of the finger tip of the middle finger of each hand and held in place by porous thermistor tape. The lead wire was secured at the fingers and wrists to prevent pulling on the probes and electrodes.

The attachment cable for the temperature probe on the dominant hand was plugged into the front panel connector of the Autogen 2000B, marked "channel A, input 1". The cable for the probe on the left hand was plugged into the connector marked "channel B, input 1".

Operating Procedure of the Autogen 2000B Temperature Unit

The front panel settings of the temperature unit were as follows: the power switch on, the meter scale selector set at x2, the baseline temperature quantifier set at the

subjects present temperature (so the needle on the metre is centred), the light feedback switch off, the meter display selector was switched back and forth between channel A and B throughout the session so that during training trials, the dominant hand was being monitored and channel A was selected and between trials, a reading from the nondominant hand was taken and channel B was selected. For the biofeedback group, the analog audio feedback mode was pressed and the pulse and reverse audio feedback modification buttons pressed. The audio feedback volume control was set at 0 for the baseline and then at 7 when the training began. The pulse rate control was 3. A plug from the external speaker was inserted into the audio connector.

For the control group, the audio feedback mode button was not pressed so the pulse and reverse modification buttons are not relevant. The external output was not connected.

EMG Electrode Placement and Hook-up

After the back of the dominant hand had been gently cleaned with alcohol, the EMG electrodes were attached. The two active electrodes were placed about one inch below the middle finger and about a half inch apart. The ground was 2 inches ventral to these for children and $2\frac{1}{2}$ inches ventral for adults (just above the wrist). Appendix D illustrates the electrode and probe placement.

The EMG electrodes were held in place on the skin by means of doughnut shaped electrode attachment discs which

have a two-sided adhesive forming a bridge between the electrodes and the skin. The cup of the electrode was filled with electrode contact medium. The attachment cable from the set of EMG electrodes were plugged into the front panel connector of the Autogen 1700, marked "input A".

Operating Procedures of the Autogen 1700 Feedback Myograph

The EMG unit was set up as follows: The power switch on, the input weighting control was turned all the way to A, the bandpass selector was turned to 400-500Hz, the metre scale selector was 1, the threshold was set so the needle on the meter fluctuated around the centre when the subject was relaxed. None of the feedback controls were activated.

I5000 Converter and P5000 Printer

Both the temperature and the EMG units were connected to the Autogen 5600 Data Acquisition centre through I5000 optically-isolated A/D converters. The I5000 which mediates the signal from the temperature unit was set at 1v on the input selector and for the EMG unit it was set at 10v. The output of the I5000 mediating the temperature signal was connected to input 1 of the D.A.C. and the output of the EMG I5000 was connected to input 2 of the D.A.C. The power for both I5000's were switched on. The D.A.C. was connected to a P5000 printer which prints out all of the data processed by the D.A.C.

ASI5600 Data Acquisition Centre

The Data Acquisition Centre (D.A.C.) was programmed as

follows:

1. Volume/standby switch on
2. Power switch on rear panel on
3. Power switch on printer on
4. The functional identities of the modalities were entered, i.e., the keyboard buttons depressed as follows:

"Channel 1 func = temp enter"

"Channel 2 func = EMG enter"

5. The duration of the subintervals into which the session was divided or the update period (UPDP) was programmed for 90 seconds.
6. The rest interval was 30 seconds
7. The number of segments (trials) into which the training session was divided was 8 for the baseline and 4 and then 8 for the training period. Since the maximum #SEG that could be programmed at a time is 10, programming during training was divided into 4 and 8 so as to allow as little disruption of training as possible.
8. The automatic restart program was not activated (Auto=0).
9. The number of decimals on the digital display was programmed at 2 (Dec=2)
10. The number of digits was 4 (#dig=4)
11. The format, which determines whether standard deviation or liability is computed, was 1, requesting standard.

deviations

12. I.D. was entered as subject's initial and last name.

13. D time, for temperature, which specifies the time interval over which the signal is averaged for display on the D.A.C. was 1 (sec.)

14. When all parameters were programmed and the monitoring and/or feedback was to begin, the start button was pressed.

APPENDIX B
Biofeedback Instructions

For this experiment, I am trying to learn more about people's ability to control their own skin temperature. It seems that people can learn to change their own skin temperature. However, it is apparent that relaxation is an important part of this training. I'll be using thermistors to measure your finger temperature. These are just tiny bead-like sensors which I will tape to your finger tips. I will tape one of these to the middle finger tip of each hand where they will sense any temperature changes. Other electrodes will be taped to the back of your right hand. These are EMG electrodes and will monitor the muscles in that hand. These electrodes are perfectly harmless. They are taped to your skin and read temperature and muscle activity only from the surface of your hands. So nothing about them will hurt you and you should feel no more worried or uncomfortable about them than you would about having a piece of tape or a bandaid on your hand. (tape stopped, probes and electrodes attached)

Since these electrodes are so sensitive they are easily affected by you moving around or even by you changing how you breath and then it is hard for me to understand what your readings mean. Therefore, it is important that you try to stay still while I monitor you. If you get comfortable

before we begin, you will find you don't have to move much during the session. Also, if you breath comfortably and easily when we begin monitoring you won't have to change how you breath during the session. For the next while I will be measuring your temperature and muscle activity. So for the next 15 minutes all you have to do is get comfortable and relaxed, and move as little as possible. To help you keep your hands in the same position throughout the session, I have cardboard patterns for you to rest them in. Just place your hands loosely in these patterns and rest them at your sides. Also I would like you to keep your eyes open while I am monitoring. Remember, I am just monitoring now. There is nothing for you to do but to stay relaxed and quiet. I'll be playing music for most of this period to make the time as relaxing as possible.

You may notice me pushing some buttons throughout the session. This is just so I can switch the monitor from one hand to the other. Now get comfortable and remember, I am just monitoring now. There is nothing for you to do but to stay relaxed and quiet.

(Baseline Recording)

O.K. we're ready to start training now. The kind of training we will be using is called biofeedback and many people have found it an easy way to learn how to increase their own hand or finger temperature. Basically, biofeedback training works by giving you information about your own

body. An example of biofeedback is weighing yourself on the bathroom scale. When you are trying to control your weight, the scale tells you if you are gaining or losing weight.

In this experiment, the feedback will be a tone and numbers telling you what your finger temperature is. These will tell you how well you are controlling the temperature of the middle finger on your right hand. As your finger temperature increases, you will hear the pitch of the tone decrease. If your finger cools, the pitch of the tone will increase (demonstrate). Similarly the numbers on the panel will increase and decrease as your finger temperature increases and decreases.

In this study, I want you to warm your finger so you are to use the information provided by the tone and the numbers to try to increase the temperature of the middle finger on your right hand. This is easy to do. In fact most people don't expect it to be so simple and try too hard. You don't have to try hard for this kind of training--instead of putting out any active effort, you just need to stay relaxed and to mentally will the response. Just concentrate on the tone and on the numbers and on how you feel when your finger temperature is increasing.

Remember, there is no reason for you to feel worried about either the equipment or the training. Although I am recording your responses I am not judging how well you do. This finger warming is easy to produce if you just realize that you don't have to do anything but concentrate on the

feedback and on the sensations you feel when your finger is warming. Remember, you will be trying to increase your finger temperature and to decrease the pitch of the tone--this will be indicated by the numbers on the panel.

Although this finger warming response is easy to produce, you will find at times, especially at the beginning, that the feedback indicates that your finger temperature is not increasing and that sometimes it is even decreasing. This is not unusual and should not worry you. Just continue trying to warm your finger. You should look at this training as a learning experience--something you can explore. I won't be telling you how to increase your finger temperature because different people do it different ways. You will have to discover what works best for you, but this may not happen right away. You should continue trying to warm your finger but don't worry if it takes a while.

Remember, it is important that you feel comfortable and relaxed during the training. Don't try to warm your finger by tensing your muscles or by changing how you breathe. These kinds of activities only interfere with the training. So just lie quietly and calmly, breathing easily and steadily.

The training session is divided into twelve 90-second trials with half-minute rest intervals between. At the end of each trial, the feedback will stop, so the tone will go off and the numbers will stop changing. I will tell you to stop warming your finger and to take a rest. When the half-

minute is up, I will tell you to start warming again and the feedback will be activated again. During the rest, although you will stop trying to warm your finger, it is important that you remain still and breathe steadily. You'll hear some buttons clicking--this is only me adjusting the machine so I can take some readings. That is why I am asking you to keep your hands as still as possible during the rest as well as during training. Throughout the session if you just rest your hands at your side, you'll find you are comfortable enough that you don't have to move them much. Now get comfortable, breathe easily and steadily, and move as little as possible and we'll begin.

(Training Period)

O.K., that's all the training we'll be doing today, but before I remove the probes, I want to monitor you for another 8 minutes while you are just quiet and relaxed. For the next 8 minutes you don't have to do anything but lie quietly and comfortably moving as little as possible. You can stop trying to warm your finger for this period. Again, I'll play some music to make the time as relaxing as possible. Now get comfortable, and I'll begin monitoring again.

APPENDIX CControl Instructions

For this experiment I am trying to learn more about people's ability to control their own skin temperature. It seems that people can learn to change their own skin temperature. However, it is apparent that relaxation is an important part of this training. So one of the things I am doing in this study is monitoring responses like temperature and muscle activity during periods of quiet relaxation.

I'll be using thermistors to measure your finger temperature. These are just tiny bead-like sensors which I will tape to your fingertips. I will tape one of these to the middle finger tip of each hand where they will sense any temperature changes. Other electrodes will be taped to the back of your right hand. These are EMG electrodes and will monitor the muscles in that hand. These electrodes are perfectly harmless. They are taped to your skin and read temperature and muscle activity only from the surface of your hands. So nothing about them will hurt you and you should feel no more worried or uncomfortable about them than you would about having a piece of tape or a bandaid on your hand.

(tape stopped and probes and electrodes attached)

Since these electrodes are so sensitive they are easily affected by you moving around or even by you changing how you breathe and then it is hard for me to understand what the

readings mean. Therefore, it is important that you try to stay still while I monitor you. If you get comfortable before we begin you will find that you don't have to move much during the session. Also if you breathe comfortably and easily when we begin monitoring you won't have to change how you breath during the session.

For the next while, I will be measuring your temperature and muscle activity. So for the next 15 minutes all you have to do is get comfortable and relaxed and move as little as possible. To help you keep your hands in the same position throughout the session I have cardboard patterns for you to rest them in. Just place your hands loosely in these patterns and rest them at your side. Also, I would like you to keep your eyes open while I am monitoring. I'll be playing music for the next 15 minutes to make the time as relaxing as possible. You may notice me pushing some buttons throughout the session. This is just so I can switch the monitor from one hand to the other. Now get comfortable and remember I am only monitoring. There is nothing for you to do but stay relaxed and quiet.

(Baseline Recording)

O.K., you are probably feeling quite relaxed now. For about the next 25 minutes I want you to remain relaxed, although I won't be playing any music and I will continue to monitor you. You are probably wondering what you are supposed to be doing for this time. Again, you are not to do

anything but get relaxed and lie as still and quietly as you can. This might seem like a long time to do nothing and you may feel tempted to let your eyes close and to catch a nap. However, it is important that you don't fall asleep --that is why I'm asking you to keep your eyes open. I am monitoring responses during relaxation and quiet--These are different from responses during sleep.

Again, I must ask you to remain as still as possible and to breathe easily and steadily. Remember, it is important that you feel comfortable and relaxed during the monitoring. There is no reason for you to feel worried about the equipment or the monitoring. All I am doing is recording your responses and you don't have to do anything. I'll be monitoring for 24 minutes and again you'll notice me pushing buttons--this is only to take readings from different channels. Throughout the session, if you just rest your hands loosely in the cardboard patterns at your sides, you'll find you are comfortable enough that you don't have to move them much. Now get comfortable, breathe easily and steadily, and move as little as possible and we'll begin.

(Training Phase Monitoring)

O.K., we're almost finished the session, but before I remove the probes I want to monitor you for another eight minutes while you are quiet and relaxed. So again for the next eight minutes you don't have to do anything but lie quietly and comfortably, moving as little as possible. Again

I'll play some music to make the time as relaxing as possible. Now get comfortable and I'll begin monitoring again.

APPENDIX D

Electrode and Thermistor Placements

Temperature Probe Attached to Middle Finger
of Both Right and Left Hands

APPENDIX E
Credibility Scale

Please choose the answer which best describes how you feel.

I expect to increase my temperature ---

1. a great deal
2. somewhat
3. a little
4. not at all

APPENDIX FLetter to Parents

Dear Sir or Madam,

I am conducting a study at the Psychology Department of Carleton University. We are trying to learn more about people's ability to voluntarily change their skin temperature.

Past research has indicated that warming hands or fingers has been effective in relieving painful symptoms associated with migraine headache and Raynaud's disease. It has been suggested and in some instances demonstrated that training patients to voluntarily warm their hands or fingers may prove to be a viable nondrug treatment for migraine headache and some other circulatory related diseases. In this study, we are attempting to train people who are not afflicted by any of these disorders to voluntarily warm their fingers in an attempt to develop effective training techniques.

There is especially a need for more research with children. Since children have less tolerance for most analgesics, it is important that research is done on potential nondrug treatments for childhood migraine. In the present study we will be examining a means of training finger warming in right-handed children between the ages of 10 and 12 who do not get migraine headaches or have any learning disabilities or vascular or neurological diseases.

If you should agree to have your child be in the study his or her participation will involve 2 1/2-hour sessions at Carleton University (St. Pat's) scheduled at our mutual convenience. During these sessions your child will be monitored by some training equipment which involves having two temperature probes and three EMG electrodes, both which are harmless surface probes, attached to the hands. The sessions present no risk or danger to the participant.

Some participants will receive temperature training and others will be monitored but not trained, so it is important that you tell

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your child only that this is a study investigating finger temperature. When participants come to the University the experimenter will explain the details to them and at the end of the experiment they will have the study explained to them in full. At the completion of the experiment subjects will be paid \$10 dollars for their participation.

The results of this study should help us to learn more about voluntary control of human skin temperature. If you are interested in having your child involved in the study please write your name and number and your child's name in the spaces below and I will call you in the next two weeks. If you are not sure you would like your child to participate and would like to talk to me about it please write your name and number and I'll call you to answer any questions you have.

Thank you for your cooperation,

Anne Pawlak

NAME OF PARENT OR GUARDIAN

TELEPHONE NUMBER

CHILD'S NAME

Carleton University

Department of Psychology

Informed Consent Agreement

This project has been reviewed and approved by the Psychology Department Committee on Research with Human Subjects as preserving safeguards of subjects' privacy, welfare and civil liberties. The Chairperson of the Committee may be reached through the Department of Psychology, Carleton University.

I hereby agree to cooperate and have my child _____ participate in the research project on finger temperature training to be conducted by Anne Pawlak of the Psychology Department of Carleton University as experimenter.

I acknowledge that the experimenter has informed me about my child's participation in the investigation. I also acknowledge that my child's participation in the investigation has been fully explained to me, and that should his or her participation in the experiment be altered in any way, I will be duly informed by the experimenter of the changes.

I understand that I have the freedom and the right to withdraw my child from the experiment at any time without question or reprimand by either the principal investigator or Carleton University.

Signature of parent or guardian

Date

Principal investigator

Street Address

City, Province

Carleton University
Department of Psychology
Informed Consent Agreement

This project has been reviewed and approved by the Psychology Department Committee on Research with Human Subjects as preserving safeguards of subjects' privacy, welfare and civil liberties. The Chairperson of the Committee may be reached through the Department of Psychology, Carleton University.

I hereby agree to cooperate and participate in the research project on finger temperature training to be conducted by Anne Pawlak of the Psychology Department of Carleton University as experimenter.

I acknowledge that my participation in the investigation has been fully explained to me, and that should my participation in the experiment be altered in any way I will be duly informed by the experimenter of the changes.

I understand that I have the freedom and the right to withdraw from the experiment at any time without question or reprimand by either the principal investigator or Carleton University.

Participants Signature

Date

Principal Investigator

Street Address

City, Province

END

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FIN