



Developmental differences in children in hand temperature control through biofeedback
by Jane Frazier Georgitis

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Psychology

Montana State University

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Abstract:

The purpose of this experiment was to determine whether younger children are more adept at hand temperature biofeedback control than are older children. Six 6-year-olds and six 11-year-olds participated in the study. Subjects attempted to mentally turn on a tone by changing hand temperature in the appropriate direction, either warming or cooling the left or right hand. Two separate Autogen 2000 biofeedback thermometers recorded hand temperature from the web dorsum of both the feedback and nonfeedback hands. Subjects attempted all four possible hand and direction combinations in each of four sessions.

Nonfeedback and feedback hand responses tended to parallel each other. Younger children and older children increased hand temperature during both warming and cooling trials. The younger children warmed their hands to a greater extent than did older children. Warming increases were greater than cooling increases for the younger group's nonfeedback hand, but only for the first session, a finding which suggests a possible slight ability of the younger group to control temperature. Explanations for the apparent loss of control in subsequent sessions include lack of attention to the task, motivation, and overall task difficulty.

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THROUGH BIOFEEDBACK

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

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INTRODUCTION

Research shows that voluntary control of various autonomically mediated responses is possible through biofeedback. One physiological function of particular interest is peripheral temperature control. Temperature control appears to have some practical applications in the treatment of migraine headaches (Fahrion, 1977; Medina, Diamond, & Franklin, 1976), Raynaud's disease (Freedman, 1987; May & Weber, 1976; Sedlacek, 1976; Stambrook, Hamel, & Carter, 1988; Surwit, 1973), hyperactivity (Hershey, 1983), hypertension (Blanchard, McCaffrey, Musso, & Gerardi, 1987), rheumatoid arthritis (Mitchell, 1986), and tinnitus (Duckro, Pollard, Bray, & Scheiter, 1984).

Most of the literature on hand temperature control through biofeedback indicates that adult subjects seem to be able to consistently achieve a certain amount of hand or finger temperature control. Some subjects have obtained large temperature changes of 15° F and more (Roberts, Kewman, & MacDonald, 1973; Taub & Emurian, 1976). However, no additional research has replicated these large changes in temperature. Generally, control is in the form of small-magnitude temperature changes.

It is interesting to note that the temperature

changes are slightly greater for decreasing hand temperature than for increasing hand temperature (Keefe & Gardner, 1979; Surwit, Shapiro, & Feld, 1976; Taub & Emurian, 1976). This greater effect in cooling of hand temperature may be due to the experimental situation itself and may not necessarily be due to a greater ability of humans to lower peripheral temperature. States of stress or anxiety cause the adrenal glands to secrete two hormones, epinephrine and norepinephrine. This response corresponds to the "fight or flight" phenomenon, in which blood vessels are constricted in the skin and the digestive system, diverting blood to areas of the body more important to physical exertion. In most experimental situations, experimenters hook subjects up to unfamiliar electronic equipment in an unfamiliar room. Often, experimenters are unknown to the subjects. Subjects may have difficulty completely relaxing in such a setting. Therefore, in experimental situations, subjects may find lowering of hand temperature easier since a state of nervousness may augment the response.

Another factor which may explain the greater cooling biofeedback effects is somatic mediation. Lynch, Schuri, and D'Anna (1976) explored the influence of two isometric exercises on various autonomic functions including finger temperature. Subjects performed each of the two isometric exercises, a hand grip and dorsiflexion of the foot, in

three levels of exertion. The general findings showed a significant decrease in fingertip temperature for all exercises, at each locality which was proportional to the level of exertion.

King and Montgomery (1981) also examined the effects of somatic maneuvers on skin temperature control. In Experiment 1, King and Montgomery instructed the 24 subjects to raise their skin temperature. Experimenters told 8 of those subjects to relax, and told 8 to use muscular activity to raise finger temperature. The other 8 subjects, as a control group, had no information other than to raise fingertip temperature. The results indicated that muscle tension was conducive to hand warming efforts. There were no significant increases in temperature for the other two groups.

King and Montgomery (1981) then explored the idea that somatic activity could produce bi-directional temperature changes. The experimenters divided the 20 subjects into two groups, telling one group to increase hand temperature and the other to decrease it. The experimenters encouraged both groups to use somatic activity as an aid to temperature control. Results showed that both increasing and decreasing temperatures through biofeedback was possible using somatic mediation, although the muscle activity for the two groups was different. Subjects in the warming group generally reported

intermittent muscular activity of the ipsilateral arm, whereas subjects in the cooling group utilized intermittent muscular activity in the contralateral arm coupled with continuous tension in the ipsilateral arm. The experimenters did not statistically analyze the verbal reports, however. The authors then made the assumption that in order to control hand temperature in either direction, one must resort to muscle activation. This statement seems to contradict the notion that relaxation seems to enhance a warming response.

According to Miller (1969), bi-directional control is less likely to be due to somatic mediation or other mediating factors. If a subject has found a trick to change hand temperature in one direction, it will very likely not work for thermal change in the other. King and Montgomery appear to discount this statement on the surface. However, it is interesting to note that in the King and Montgomery study, subjects were not learning actual bi-directional control. Each subject was making a temperature change in one direction only. The experimenters gave ample time to the subjects for perfecting muscle activity which enhanced the desired temperature response.

Lynch, Hama, Kohn, and Miller (1976) proposed that children might be better able to control hand temperature. The experimenters conjectured that children may be better

learners than adults for several reasons. Children are known to be more adept at learning language and some motor skills than adults, so it is not unlikely that children possess other abilities superior to those of adults. Secondly, children are easily motivated to learn and may not readily question the possibility of learning such a response as hand temperature change.

Experimenters in the Lynch et al. study watched the subjects closely for any movement or tensing, and monitored respiration. Four subjects (average age 10.98 years) attempted to cool the dominant hand relative to the other hand for the first six sessions, and tried to warm the dominant hand in relation to the other hand for the second six sessions. The feedback consisted of a needle on a meter which moved towards the warmer hand. Three of the four subjects produced significant temperature changes in the appropriate directions. Subjects utilized differential cooling of both hands most often to produce temperature differences between the two hands, which appears to be consistent with the idea that cooling through biofeedback may be enhanced by the experimental situation and may be easier to produce.

Being aware of the possibility of somatic mediation causing the biofeedback effects, especially in cooling, Lynch, et al. then increased the specificity of the required response. The two subjects with the best

performance attempted to produce a temperature differential between the second and fourth fingers of the dominant hand. Experimenters randomly assigned relative warming of one or the other fingers for each of the eight sessions. Although both subjects produced appropriate temperature differentials, only one subject's performance was statistically significant. This research demonstrated that peripheral temperature control is possible in a case where somatic mediation or respiration changes should have a minimal effect. Based on the authors' previous work with adult subjects, Lynch et al. suggested that children may be superior to adults in acquiring this skin temperature control.

Lynch and Schuri (1978) continued this research direction by comparing hand temperature regulation of eight children (ages 10-12 years) with eight of their parents (ages 30-42 years). Methods and instructions were similar to those of Lynch, Hama, Kohn, and Miller (1976). Experimenters instructed the subjects to relax. Trials consisted of 8 min of warming one hand relative to the other, followed by 8 min of warming the other hand relative to the first. Individually, three of the eight children showed significant correct temperature deviations from baseline, whereas only one adult varied significantly from the baseline measures (but in the opposite direction of the desired response). The results may suggest a

superior ability among children in controlling hand temperature, although as a group, the children did not show significant biofeedback effects.

One child in the Lynch and Schuri experiment seemed to possess an extraordinary ability to produce appropriate temperature differences. In order to further analyze her performance, this subject participated in three more sessions. Observations indicated a tensing of the deltoid muscle on the side of the hand that was being cooled. When the subject used an EMG to decrease this muscular activity during biofeedback sessions, the subject's thermal control diminished, although the subject still produced significant hand temperature differentials. The experimenters could not rule out the possibility of other muscles mediating the response.

The overall results still suggest that children may have superior ability to control hand temperature when compared to adults. However, Hama et al. (1979) compared hand temperature control of 11-year-old children and college students and found no differences between the two age groups in ability to learn thermal regulation.

Suter and Loughry-Machado (1981) made a large-sample comparison between 38 children (ages 6-10 years; mean=7.98) and 38 of their parents (ages 19-58 years; mean=32.4). General instructions were to mentally turn on an audio feedback tone without moving. The tone indicated

rate of change in skin temperature in the appropriate direction, either warming or cooling of the left or right hands. Instead of looking for temperature differences between hands, the experimenters gave feedback for one hand only. The four trials for each session consisted of one warming trial and one cooling trial for each hand. The researchers took temperature readings from the web dorsum of each hand.

The authors found significant correct temperature deviations from baseline measures in both the warming and cooling trials among the children in the two biofeedback sessions, whereas adults as a group, showed no significant deviation from baseline temperature in the same number of sessions.

These highly significant findings seem to support the hypothesis that childrens' ability to control hand temperature is greater than that of adults. Suter and Loughry-Machado offered several explanations for their results. One was that children are just faster learners of thermal control. According to a study by Keefe (1975), adults' thermal control after four sessions was poor, whereas by the eighth session, temperature control had developed. The authors also suggested that children may have been more likely than adults to utilize muscle mediation, potentiating biofeedback effects, although they offered no objective support for this statement.

Experimenters did not monitor muscular activity with EMG, but did observe subjects throughout all sessions and instructed them not to make any movements. Somatic maneuvers, such as muscle flexing, do not influence temperature measures taken from the web dorsum as easily as temperature measures taken from the fingertip, according to Taub and Emurian (1976). Still, one cannot ignore the possibility that somatic mediation influenced the results.

The role of cognitive factors may also have been an important variable in the adult-child difference of biofeedback performance reported by Suter and Loughry-Machado. They suggested that adults have a more "analytical" approach to turning on the tone than children, and concluded that adults thought they were supposed to be "doing or thinking something" to operate the tone. This cognitive approach appears to impede biofeedback performance according to a study by Taub and Emurian (1976). This is further supported by Herzfeld and Taub (1980) who reported that their most skilled adult subjects actually utilize an absence of strategy.

Suter, Fredericson, and Portuesi (1983) attempted to replicate the Suter and Loughry-Machado experiment and proposed to assess the importance of cognitive and somatic mediation strategies in control of hand temperature. Subjects for Experiment 1 were 24 children and 24 of their

parents. Methods were similar to the Suter and Loughry-Machado study. Experimenters monitored muscle activity of the right forearm and deltoid muscles with an EMG instrument. Instructions to the subjects were to warm or cool the right hand "using any mental technique they wished to use" provided they did not move or tense muscles during feedback trials. Experimenters also casually inquired between trials as to the cognitive strategy being used for the previous feedback interval.

Analysis of results indicated that children's biofeedback superiority over adults was only minimal. Hand temperature tended to increase during warming as well as cooling trials for all subjects, but among children, the increase was less for cooling trials. This greater temperature increase during warming trials was significant for the first of four sessions only. Adults showed no differences between warming and cooling conditions.

Upon examination of strategies for controlling temperature, the experimenters found that children were more likely than adults to not have a particular reported strategy, whereas adults were more likely to utilize imagery or emotional strategies to control temperature. Investigators monitored the right forearm flexor and right deltoid muscles for activity during biofeedback trials. Greater EMG activity was more prevalent in hand-warming sessions than in cooling sessions, especially with the

adult subjects. Further analysis showed that actual skin temperature changes and simultaneous EMG recordings were not consistently correlated. In Experiment 2 of the same study, the experimenters did not find one type of strategy to be more effective than the other. They did not monitor EMG during Experiment 2. A third study utilized the children who were the best temperature regulators from Experiment 2. Experimenters again monitored muscular activity with EMG recordings as was done in Experiment 1. There was no significant relationship between EMG and temperature change for any participant. Children as a group produced minimal but statistically significant temperature changes in the correct direction.

The failure to replicate the strong biofeedback effects of the Suter and Loughry-Machado (1981) study may be due to the modifications of the original methods. One change was that of EMG monitoring. Although Suter and Loughry-Machado instructed subjects not to move and visually monitored the subjects for movement and tensing, it is impossible to say whether or not somatic activity occurred. It is interesting to note that in the Suter et al. study, in the two experiments where EMG was monitored, children demonstrated significant thermal control. In Experiment 2, the authors did not monitor muscular activity. Although other important variables were manipulated, subjects in this experiment failed to

demonstrate biofeedback control. The researchers concluded that when reasonable controls are used, children and adults do not rely on somatic mediation to control skin temperature. However, since these subjects obtained little or no control, this statement is hardly convincing.

Another important difference between the Suter and Loughry-Machado study and the experiments by Suter et al., involved cognitive mediation. Suter and Loughry-Machado instructed participants to turn on the tone mentally, with only a superficial mention of change of skin temperature. This left open the opportunity for subjects to adopt a strategy or an absence of strategy to control skin temperature. However, Suter et al., in Experiment 1, when asking subjects to use any mental technique they wished, may have implied that thinking about something or doing something would aid in biofeedback control. Experiment 2 involved an even stronger encouragement to use imagery and emotional strategies to regulate skin temperature. Instructions for Experiment 3 were similar to Experiment 1 but subjects had already participated in Experiment 2 and may have established ineffective cognitive sets for control strategies.

I should note again, however, that an absence of strategy characterizes the most successful thermoregulators (Herzfeld & Taub, 1980). The experimenters themselves in the Suter et al. study may

have influenced the subjects' performances by implying that conscious cognitive or emotional strategy or strategies exist which increase the voluntary control of skin temperature, when actually, this may not be the case. On the contrary, such strategies may inhibit successful performance.

One other difference between the 1981 and the 1983 study is that the experimenter interacting with the subjects in each study was a different person. According to Taub and School (1978), the experimenter himself can have an extremely strong influence on biofeedback scores of participants. Experimenter characteristics, some of which have been shown to shape biofeedback performance include attitude (warm and friendly vs. cool and distant), expectations (high vs. low) (Segreto-Burres & Kotses, 1982) and possibly familiarity (Suter et al., 1983). Systematic study of these variables in the Suter et al. study was not conducted. Therefore, the relative influence of these factors on subjects' performance in temperature biofeedback studies is conjectural.

The question still seems to remain whether children are proficient temperature regulators. Despite some conflicting findings previously mentioned, there appears to be some indication that children are superior to adults at hand temperature control.

Hunter, Russell, Russell, and Zimmerman (1976) found

significant control of hand temperature among children as subjects when comparing thermal control of normal children to that of learning disabled children (ages 7-9 years; mean age = 8.5). An interesting finding of this study was that the younger subjects (both normal and learning disabled) were significantly better at controlling fingertip temperature than the older subjects.

Could there be an age difference among children in ability to regulate temperature? This is a matter of interest therapeutically, since childhood biofeedback training as a treatment for migraine headaches, for instance, may be more effective than training of adolescents or adults.

The notion of a sensitive period (of learning or development) perhaps is appropriate here since the greater ability of thermal control may be found at a lower level of maturation. What factors might contribute to the presence of a possible sensitive period of peripheral temperature control learning or performance?

According to Bronson (1965), neurological maturation continues through puberty in three levels, the second being most interesting to the present discussion because of its relation to thermal control. The second level of maturation of the nervous system includes the development of the hypothalamus, the thalamus, and the limbic system. According to Bronson, little is known about the rates of

human development of these specific brain areas (Epstein, 1974, 1978). The hypothalamus functions as the temperature regulating center of the body. Specifically, the preoptic area of the hypothalamus causes vasodilation of blood vessels, resulting in heat loss, while the area dorsal to the mamillary bodies has an analogous function of constricting blood vessels causing body heat conservation (Martinez, 1982).

At the present time, we do not know the timing of developmental changes in the neurology affecting these temperature control areas. All that can be said is that a neurological basis for superior temperature control among children is not implausible. Perhaps children show more variability in hand temperature at all times due to a more unstable thermoregulatory center, which may enable them to produce and perhaps control greater temperature fluctuations in testing situations.

Major physical growth and development periods also occur during childhood. These developmental stages are from birth to approximately the beginning of the sixth year, from the sixth year to the ninth year, prepuberty, and adolescence. These growth periods also correspond to brain growth and perhaps neurological development as well (Epstein, 1974, 1978). Since sensitive periods are thought to be maturationally determined, perhaps one of these stages corresponds to a sensitive period for peripheral

skin temperature control learning.

There are other developmental changes during childhood which may explain why young children might be better than older children or adults at biofeedback temperature regulation. Cognitive mediation discussed earlier, may play an important part in age differences in thermal control. Piaget (1952) among others, has noted that children exhibit consistent patterns of judgment and reasoning, depending upon the age of the child. Somewhere between the ages of five and seven, a child begins to rely on symbols to carry out mental functions or operations. Younger children tend to use more physical activities as a basis for thinking. Older children also seem to be able to think using symbols and see relationships better than younger ones. Young children have more difficulty in seeing situations from someone else's perspective.

The idea of developmental changes in cognitive strategy in children is an interesting one in relation to biofeedback training. It is especially intriguing that increased symbolic thought occurs in older children and adults and also is a more common biofeedback strategy among adults, compared to children (Suter et al., 1983). At the same time, the lack of a strategy, utilized by children more often in the Suter et al. study, appears to be more successful than imagery or emotional symbolism (Herzfeld & Taub, 1980).

The notion of age differences among children in biofeedback ability perhaps explains why some comparison studies between children and adults lack significant findings. Lynch and Schuri (1978) and Hama, et al. (1979) both used older children (10-12 years old) as subjects. Suter and Loughry-Machado, on the other hand, obtained significant results using children with an age range of 6 through 10 years, with 7.98 years as the average age. Could the younger age of the children have been a factor in the experimental outcomes?

The present study is an attempt to further clarify the relationship between age and hand temperature control through biofeedback in children. Based on the above evidence, I expect that younger subjects will perform better than older subjects.

METHODS

Subjects

The Bozeman Public School Assistant Superintendent granted permission for fliers describing the present experiment to be distributed in two fifth-grade classes and two kindergarten classes. I contacted all interested students' parents and obtained written permission for participation in the study.

A total of 12 female subjects participated in this study. Six subjects were recruited from each of two age groups: 5-6 years and 10-11 years. Selection was based on subjects' right-handedness, having no history of learning disabilities, and currently not taking any medication. Subjects received a set of colored pens as a reward for participating in all four sessions.

Apparatus

Subjects sat in a large comfortable chair in the central room of the Biofeedback Laboratory at Montana State University. The room was quiet and temperature extremes were minimized.

Calibration of the Yellow Springs thermistors, model 729, took place prior to the experiment. It consisted of

placing the thermistors into two known temperature situations, an ice water bath and room temperature. The separate Autogen 2000 feedback thermometers monitored the temperatures. Using laboratory thermometers as a standard, I corrected the Autogen 2000s, accordingly.

Prior to the initial session, the experimenter traced each subject's hands on a piece of paper which was placed on a board and laid across the arms of the chair. Hand position thus remained reasonably consistent between sessions for each individual by placing the subject's hands on the established positions on the paper.

The experimenter then attached the thermistors to the web dorsum of each hand. Each subject rested her elbows on the arms of the chair and her hands on the paper hand guides. Separate Autogen 2000 feedback thermometers monitored the temperature of each hand. The feedback consisted of an audio tone which sounded when skin temperature of the designated hand changed in the appropriate direction at a rate of at least $0.006^{\circ}\text{C/sec}$.

An Apple computer located in a separate room sampled skin temperature readings at ten-second intervals during stabilization, baseline, and feedback trials for each session. The computer averaged these values every 50 seconds and recorded the results as standard four-decimal place values at increments of approximately 0.01°C .

Procedure

Each subject participated in four sessions, each consisting of a 5-min. stabilization period, a 5-min. baseline period, both with no feedback, followed by four 5-min. trials with feedback. The four trials included all four combinations of warming and cooling the left and right hands the order randomized for each session. The feedback was for the designated hand only.

I told each subject that she was going to be warming and cooling her hand temperature. The machines were going to help by making a noise when temperature change was correct. Instructions were then to "turn on the tone mentally without moving or tightening muscles". Between each trial, I reminded each subject that she would again be changing hand temperature and to "try to turn on the tone mentally without moving". Subjects were unaware of the predetermined direction (warming or cooling) and which hand was in the feedback loop (left or right) during the entire experiment. I viewed the subjects from behind throughout the trials to assure that no movement, muscle tensing, or abnormal respiration occurred.

RESULTS

I performed five separate analyses of variance on the data for each of five dependent variables in relationship to the independent variables of age, session number, and direction of temperature change in each hand. The five dependent variables for the analysis are absolute temperature change from the beginning to the end of each trial for the feedback hand, absolute temperature change for the hand not in the feedback loop (nonfeedback hand), temperature change in the reinforced direction (correct temperature change) for the feedback hand, correct temperature change for the nonfeedback hand, and the temperature difference between the two hands at the end of each trial. Significant differences between age groups are of special interest.

Temperature Change for the Feedback Hand

A four-way (Age x Subject x Session x Direction) nested, with subjects nested within age, analysis of variance was performed on the temperature change data for the feedback hand.

The difference between the two groups in overall temperature change approaches significance, $F(1, 10) = 7.35$, $p = .02$. Regardless of whether feedback was for

warming or cooling, the younger group increased hand temperature 0.32° C across all trials and sessions, while the older group increased temperature only 0.15° C. Further, the interaction between Age x Sessions also approaches significance, $F(3, 30) = 3.55$, $p = .02$, with regard to the feedback hand temperature change. However, linear trends across sessions between the two groups do not differ significantly.

Temperature Change for the Nonfeedback Hand

The hand not receiving feedback was monitored for temperature change as well. Analysis for the nonfeedback hand is similar to the method used for the feedback hand. Again, both groups increased the nonfeedback hand temperature regardless of the direction being reinforced, but the younger group's increase in hand temperature is 0.41° C while the older group's increase is only 0.12° C. Group differences are significant, $F(1, 10) = 9.60$, $p = .01$.

A Group x Direction interaction is also significant for the nonfeedback hand, $F(12, 120) = 1.70$, $p < .005$ (Figure 1). Post hoc comparisons were made to determine which, if any, of the directions differed between groups. Regardless of direction, the right hand temperature changes of the nonfeedback hands approach significance different between groups, $t(10) = 2.78$, $p < .05$, for

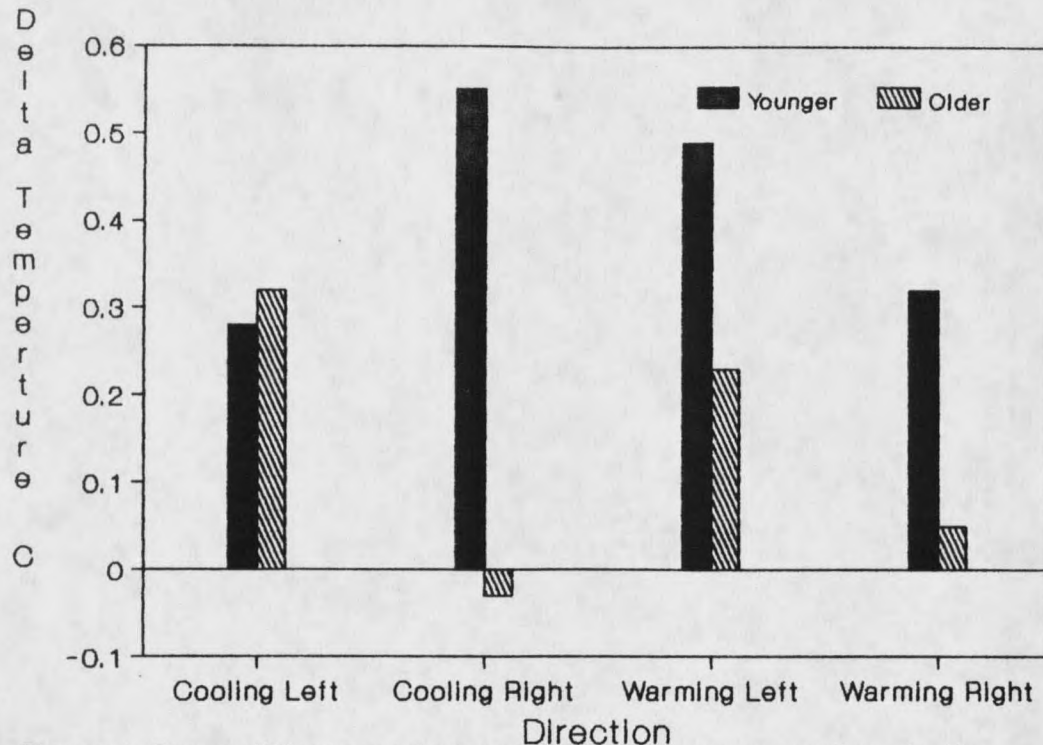


Figure 1. Group differences in temperature change according to the reinforced direction for the nonfeedback hand, $F(12, 120) = 1.70$, $p < .005$

warming the right hand, and $t(10) = 2.61$, $p < .05$ for cooling. In the cooling right hand trials the younger group warmed the nonfeedback (i.e., left hand) 0.54°C whereas the older group cooled the left hand 0.03°C in those trials. Also during warming the right hand trials, the older group cooled the left hand, (i.e., nonfeedback hand) 0.05°C and the younger group warmed their nonfeedback hand 0.32°C .

Feedback Hand Success

Since there seemed to be some success in the younger group, especially for warming trials, a four-way nested ANOVA, (Age x Subject x Session x Direction, with subject nested within age) was performed on the successful change data for the feedback hand. Temperature change in the appropriate direction was given a positive sign, and change in the wrong direction was assigned its negative value. A direction (within session) effect is highly significant, $F(12, 120) = 3.79$, $p < .0001$ (see Figure 2).

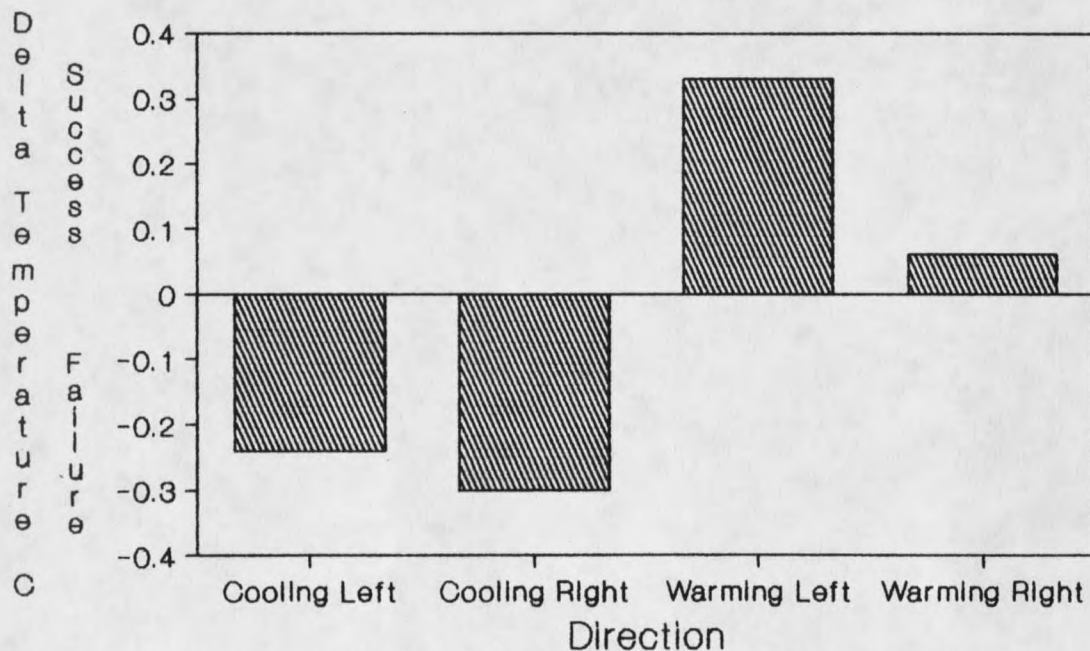


Figure 2. Directional differences in successful temperature change of the feedback hand for both groups, $F(12, 120) = 3.79$, $p < .0001$.

Cooling sessions are unsuccessful overall while warming sessions are generally successful, $t(10) = 7.71$, $p < .0001$. No significant group differences exist.

Nonfeedback Hand Success

Nonfeedback hand success analysis is similar to the feedback hand success analysis. There is a significant Group x Session interaction, $F(3, 30) = 7.37$, $p < .001$ for the nonfeedback hand (see Figure 3).

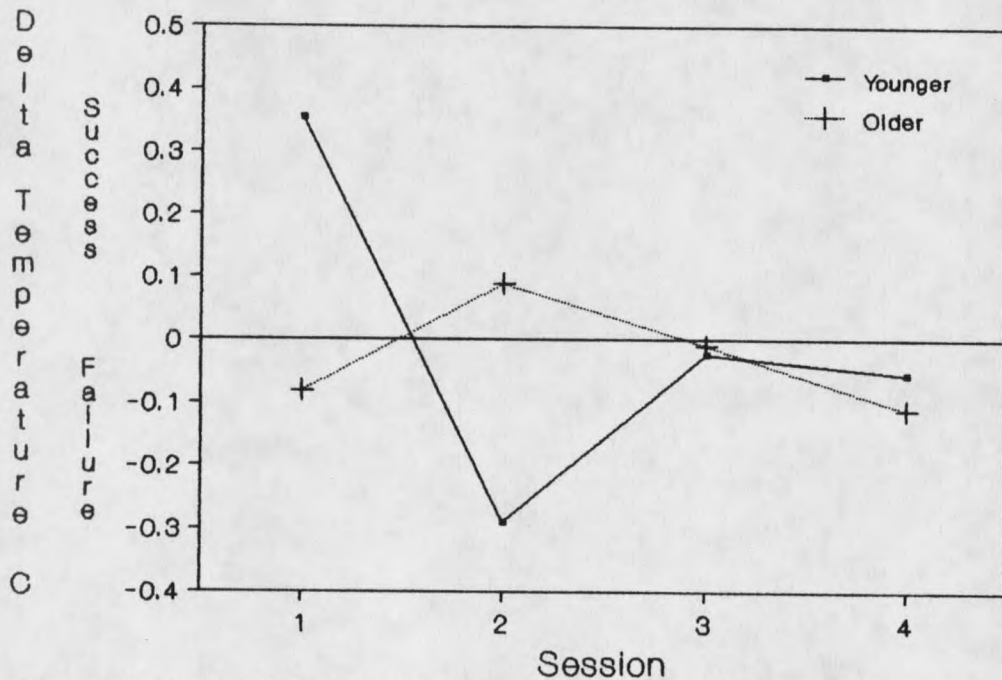


Figure 3. Group differences in successful temperature change of the nonfeedback hand by sessions, $F(3, 30) = 7.37$, $p < .001$.

Figure 3 shows that the younger group produces a high degree of success in the first session while the older group is largely unsuccessful, $t(10) = 3.34$, $p < .01$. The younger group fails to make a correct temperature change during the second session, whereas the older group is marginally successful. The difference between the two groups for the second session approaches significance, $t(10) = 2.40$, $p < .05$. The two groups do not differ from each other in the other two sessions, nor is there a difference between groups in linear trends across the four sessions.

Successful temperature change of the nonfeedback hand depends critically on the hand and direction being reinforced, $F(12, 120) = 4.32$, $p < .0001$ (see Figure 4). Again, as seen in previous analysis for the feedback hand, warming success in the nonfeedback hand is greater than cooling success, $t(10) = 7.80$, $p < .0001$.

There is a significant three-way interaction (Group x Session x Direction) for the nonfeedback hand $F(12, 120) = 2.43$, $p < .01$ (see Figures 5 and 6). Group 1, the younger group, differs significantly from Group 2 in Session 1, $t(10) = 3.34$, $p < .01$, and in Session 2 the difference approaches significance, $t(10) = 2.40$, $p < .05$. In other post hoc comparisons, group differences approach significance in right hand warming, $t(10) = 2.78$, $p < .05$, and cooling, $t(10) = 2.61$, $p < .05$, but

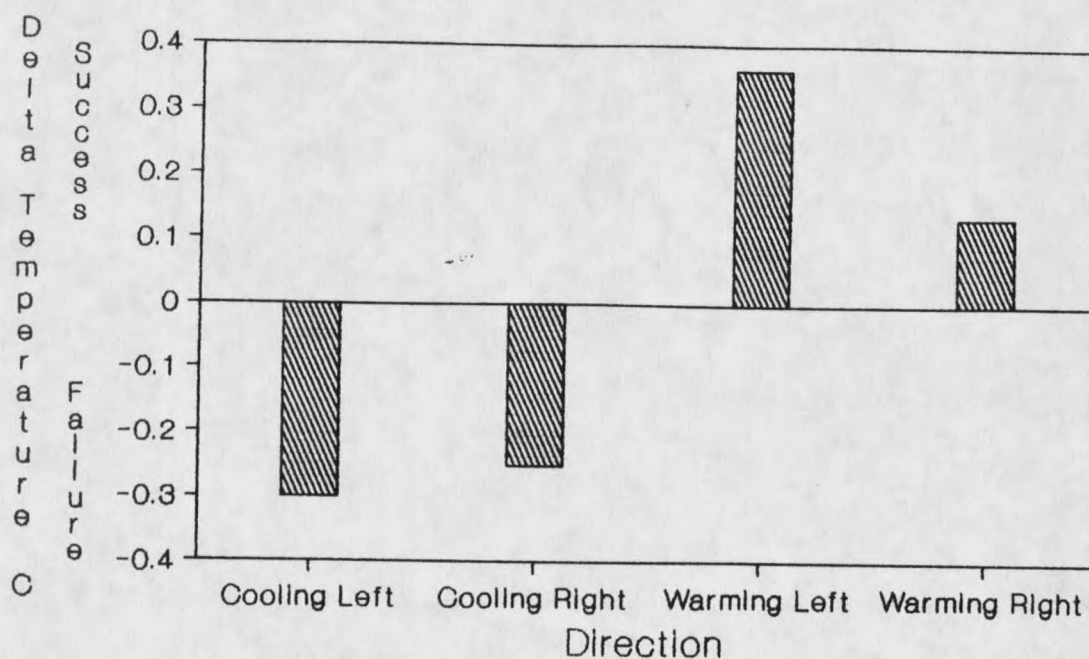


Figure 4. Directional differences in successful temperature change of the nonfeedback hand for both groups, $F(12, 120) = 4.32$, $p < .0001$.

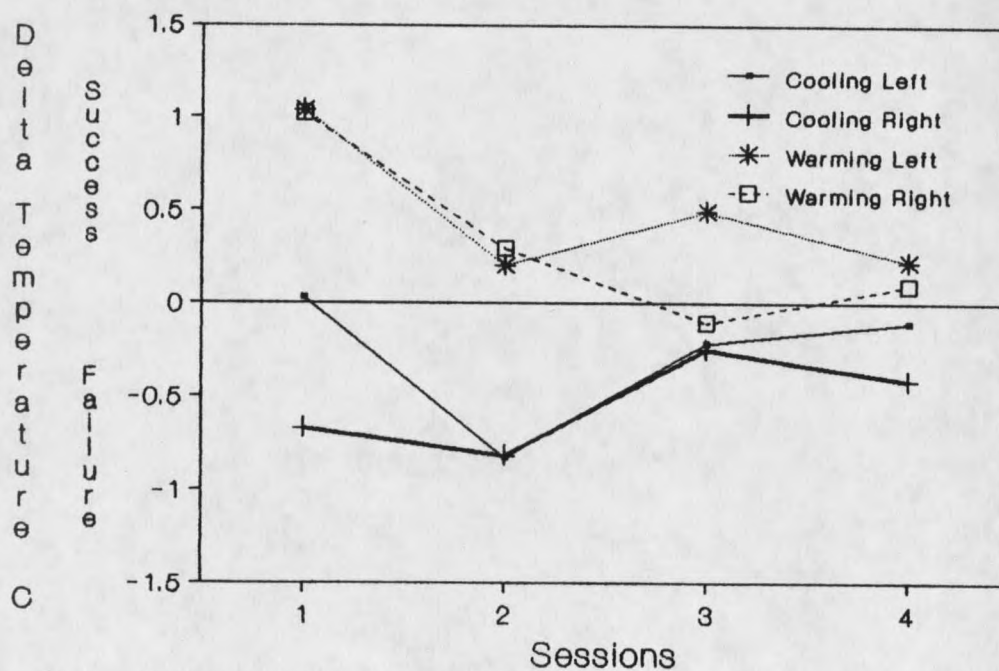


Figure 5. Group 1 directional differences in successful temperature change of the nonfeedback hand by session, $F(12, 120) = 2.43$, $p < .01$.

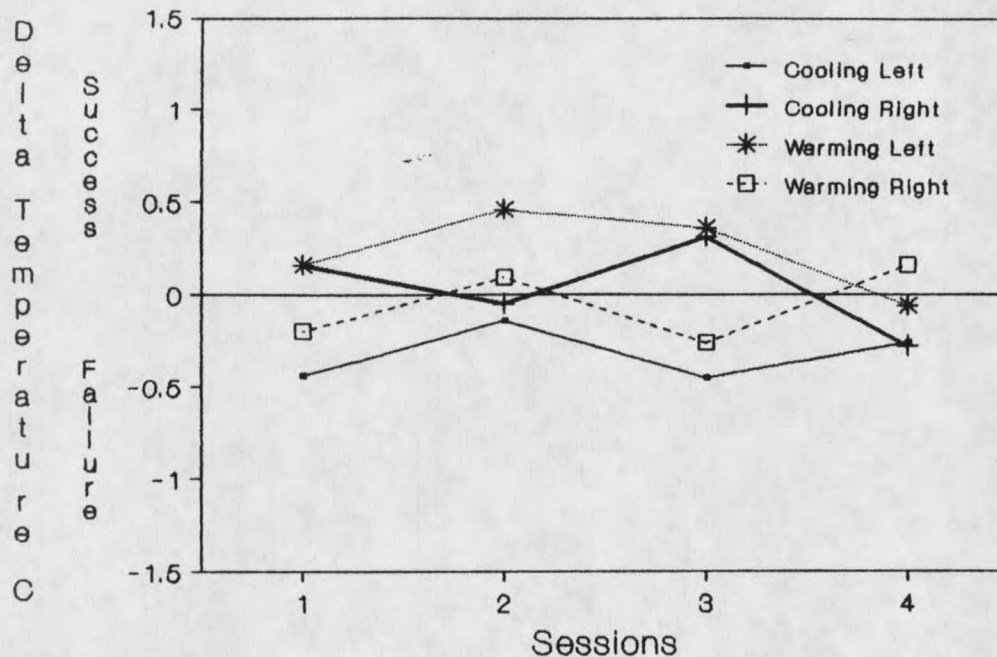


Figure 6. Group 2 directional differences in successful temperature change of the nonfeedback hand by session, $F(12, 120) = 2.43$, $p < .01$.

left hand responses do not differ significantly between groups. The relationships again are not surprising in light of previous analysis for the nonfeedback hand.

Relative Hand Temperature

A four-way ANOVA (Age x Subject x Session x Direction, with Subjects nested within Age) was performed for temperature differences to determine if there is a greater ability to cool or warm one hand relative to the

other in the specified feedback situations. There are no significant main effects or interactions for direction, group, or session.

Baseline Lability

I also analyzed baseline lability data to rule out a possible interference with temperature change results. A four-way nested ANOVA (unreplicated) was performed on the baseline temperature data, before actual feedback began. Factors were Subjects x Age (nested) x Hand (right or left) x Sessions. I found no significant age differences.

Outdoor Temperature Effects

Outdoor temperatures were very cold during the course of the experiment. This factor could have contributed to the ability of some children to warm their hands in the feedback sessions. The correlational analysis using room temperature versus outdoor temperature versus age group in relation to hand temperature change during warming trials shows no significant correlations for either group. For the young group, the relationship between the temperature change for warming trials and outdoor temperature is $r = -0.39$, $p > 0.05$ and for the old group is $r = 0.39$, $p > 0.05$. The relationship between warming trials temperature change and indoor temperature is $r = -0.21$, $p > 0.05$ and $r = 0.31$, $p > 0.05$ respectively.

Baseline Temperature and Temperature Change

A low baseline hand temperature may have caused hand temperature to subsequently increase during the biofeedback trials, not as a result of any control, but as a natural consequence of coming indoors from a much colder environment. A correlational analysis was run comparing baseline temperature and overall temperature change during each session to rule out cold outdoor temperatures as an influence in the overall warming trend during trials. The correlation is not significant, $r = -0.19$, $p > 0.05$.

DISCUSSION

The issue of whether subjects can control various autonomic functions such as skin temperature is the focus of much of the recent biofeedback research. Many factors influence results of feedback studies (Taub & School, 1978). Methodology across studies is generally inconsistent and therefore results are inconsistent as well. However, despite the diverse methodology and factors which influence biofeedback effects, many researchers have reported significant changes in autonomic functions such as hand temperature.

This experiment attempted to determine whether there are age differences in ability to raise and/or lower hand temperature. Care was taken to minimize mediation, both skeletal and cognitive, and other influencing factors such as experimenter, season, and room temperature were as consistent as possible throughout the course of the entire experiment.

The overall warming trend during the experimental trials is contrary to previous reports. It has been documented that there is a greater tendency for subjects to decrease hand temperature in experimental settings (Keefe & Gardner, 1979; Surwit, Shapiro, & Felc, 1976; Taub & Emurian, 1976). This did not necessarily point to

a greater ability to decrease hand temperature, but was attributed to the subjects' adaptation to the unfamiliar experimental setting. Researchers have identified somatic mediation as a factor also contributing to greater cooling of hand temperature in biofeedback experiments. Yet in the present experiment, young subjects in a strange and unfamiliar situation, without objective monitoring and control of somatic maneuvers produced greater warming effects overall. Further, the warming effects were greatest during the first three sessions. Warming was minimal during the last session when subjects were probably most relaxed and comfortable and when warming should have been greatest.

Why was the warming response so strong, when cooling should have been easier in the experimental situation? According to Taub and School (1978), the tendency of subjects to change their hand temperatures in a single direction may indicate inadequate stabilization periods. The present experiment did not employ criteria for determining temperature stability, but used a 10-min stabilization and baseline period. While this time is considered sufficient for most subjects to reach a stable temperature, the time required varies with the season of the year (Taub & School, 1978) and presumably with the outdoor temperature of the particular day. Taub and School also note that uni-directional temperature change is

particularly marked during the summer months. No mention is made of the effect of cold outdoor temperatures on baseline stability or hand temperature change. Outdoor temperatures were not related to warming success for either group in this experiment.

Temperature changes overall were small and the nonfeedback hand temperature changes tended to parallel those of the feedback hand, indicating that subjects were not aware which hand was in the feedback loop during experimental trials. During the first session, the younger group showed great success at making appropriate temperature changes in the nonfeedback hand. In the significant interaction of Group x Direction x Session, it can be seen that most of the success comes from the warming trials. The older group was not successful in correctly changing the nonfeedback hand temperature for any direction or session.

This success at warming trials goes against the expectation that cooling hand temperature is easier, especially in unfamiliar situations, and could point to a true ability of the younger group to regulate hand temperature for the first session. Suter, et al, (1983) also made the observation that subjects receiving feedback for warming and cooling hand temperature could raise their hand temperature to a significant degree but only for the first session.

Why might this ability, if it really does exist, manifest itself only during the first session? In the present experiment, one can argue that a decrease in concentration on the part of the younger subjects may be at fault. The attention span of five- and six-year-olds may have waned as the experiment progressed. According to Berlyne, (1970) novelty of a task increases attention to that task. This, in addition to the notion that moderate uncertainty in a situation may cause someone to be more attentive may well be one explanation for the younger group's initial success in the hand warming task. As novelty and uncertainty decreased, however, the subjects' presumed natural ability to warm their hands may have diminished as a function of their lack of attention to the task.

Another possible explanation is the reward for participation in the experiment was too distant for the younger subjects. Motivation perhaps was strong in the first session, but decreased as the experiment continued. According to Bregman and McAllister (1982), a moderately valued reward contingent upon biofeedback success was related to significantly greater success than either no reward or a highly valued reward. In the present experiment, the experimenter did not give verbal feedback to subjects regarding their performances during the experiment. Subjects' knowledge of success or failure

came only from the audio feedback tone. All subjects received a set of colored pens for participation in the experiment, but this was not contingent upon success. This may have had some influence on the poorer performances during the later sessions of the experiment.

Perhaps the somewhat disappointing biofeedback effects of the entire study are attributable to the short term training employed in the experiment. Coupled with this, subjects attempted to learn four different thermal responses, warming or cooling the left or right hand. Subjects were also unaware of which hand was receiving feedback or which direction temperature change was being reinforced. This was purposely done to eliminate the possibility of muscle mediation and cognitive strategy mediation influencing direct control. This compounded the complexity of the already difficult skill of hand temperature regulation, but in light of this, the significant warming effects of the first group for both the feedback and nonfeedback hands appears more striking. If thermal regulation is indeed possible, inadequate training time (Miller, 1985) may have resulted in the overall lack of control for both groups.

The younger group overall seemed to show a greater variability in the magnitude of temperature change produced. This may point to a possible immaturity of the temperature regulatory system based on a greater lability

in hand temperature. It can also be postulated that this fluctuation in temperature may be why the success at hand temperature regulation was produced without practice in the first session.

This hint of success for the younger group is encouraging especially in light of the negatively influencing factors in this study. Task difficulty could be reduced in future research by differentiating warming and cooling trials for the subject, so that learning a particular response such as warming is not confused with learning a cooling response. In the present study, warming and cooling trials were randomly assigned, probably confusing the subjects.

Adequate training time could also improve the results of future research. Since learning temperature changes in two different directions in one sitting is a more complex task than learning a uni-directional temperature change, learning time should be increased.

Somatic mediation may become an issue with the subjects' knowledge of the intended directional change. Monitoring of muscular activity with EMG would improve the reliability of the prospective data.

Biofeedback performance depends upon a host of factors, many of which are implicated in this discussion as adversely affecting the results of this study. Therefore the question of whether younger children are

better thermal regulators than older children cannot be answered. Perhaps with tighter controls on environmental factors, with extended training session, and a different motivational situation, more reliable findings might be obtained.

The small success attained by the younger subjects in the first session for hand warming may be of great import therapeutically. Treatment of various medical problems such as migraine headaches using biofeedback could be more expedient at an earlier age if indeed younger patients can more easily and quickly learn to raise hand temperature than their older counterparts.

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