Peripheral temperature changes during rest and gender differences in thermal biofeedback

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Abstract

Thermal biofeedback (BFB) training is used extensively in clinical psychophysiology. However, there are large individual differences in the ability to control peripheral skin temperature and the magnitude of changes obtained varies considerably across studies. The aims of this study were: (1) to investigate the relationship between spontaneous peripheral temperature changes and changes voluntarily produced through a six-session thermal BFB training and (2) to investigate whether gender or other subjects’ variables (trait anxiety, locus of control (LC) and field dependence) were related to learning of voluntary control of peripheral skin temperature. Results demonstrated that during the rest period preceding the feedback trials, there were consistent systematic temperature increases in which changes were bigger than those recorded in the BFB increase trials; among the subjects’ variables considered, the only one that correlated significantly with learning ability was gender: Females showed greater control than males. Implications for clinical practice are discussed. © 2003 Elsevier Science Inc. All rights reserved.

Keywords: Thermal biofeedback; Anxiety; Rest; Gender differences; Individual differences

Introduction

The voluntary control of peripheral vasodilation through thermal biofeedback (BFB) has been widely used in clinical psychophysiology for inducing general relaxation [1,2] and for the treatment of a number of disorders such as chronic headaches in adults [3,4] and children [5,6], Raynaud’s disease (e.g. Refs. [7,8]), and mild as well as essential hypertension (e.g. Refs. [9–11]).

Despite widespread clinical applications, research has largely disregarded many basic issues. For example, the magnitude of changes voluntarily achieved has not been given enough attention. In their review of controlled studies, King and Montgomery [12] concluded that through thermal BFB, subjects may obtain voluntary control over their peripheral skin temperature. However, the majority of studies in the review showed that better results are achieved when subjects are instructed to decrease rather than increase their temperature, as required in most clinical applications. Furthermore, the increase of temperature voluntarily obtained varies greatly from one study to another. For example, Freedman and Ianni [13] and Freedman et al. [14] report average increases of 0.4 °C; Keefe [15] and Keefe and Gardner [16] report an average increase of 1 °C, while in the increase condition Surwit and Fenton [17] showed a decrease of −1.1 °C.

Different studies have addressed methodological topics related to the clinical psychophysiology area. Most of them (e.g. Refs. [18–20]) have evaluated the reliability of psychophysiological recordings across sessions. Several studies [21–23] report a tendency for hand temperature to increase during the baseline sessions of temperature and/or EMG BFB training. No study, however, has directly evaluated the relationship between baseline recordings within each session and the magnitude of temperature changes voluntarily obtained through thermal BFB. Thus, the first aim of the present investigation was to assess whether the magnitude of spontaneous finger temperature changes recorded during the rest period preceding feedback trials is related to the magnitude of temperature changes voluntarily achieved through BFB training.

Since individual differences may affect psychophysiological responding and the reliability of psychophysiological recordings, the effect of some individual variables was
assessed to evaluate whether they might contribute to explaining the differences in the amount of voluntary temperature changes obtained in bidirectional thermal BFB training. The individual characteristics considered were gender and a set of psychological variables including trait anxiety, locus of control (LC) and field dependence. Gender was considered since it is known that peripheral temperature is higher in males than in females (e.g. Refs. [4,23]). Although it has been reported that both gender are equally able to voluntarily control their peripheral temperature [14], the higher baseline found in male subjects could limit the magnitude of increases voluntarily produced and/or learning ability because of a ceiling effect. Trait anxiety was considered in the light of research, suggesting that there is a positive relationship between trait anxiety and voluntary control of peripheral finger temperature [24,25]. Previous investigations on voluntary control of heart rate (i.e. Refs. [26,27]) have reported that subjects with an internal LC (internals) are better at increasing their heart rate, while subjects with an external LC (externals) are better at decreasing it. Thus, one might expect a similar relationship for the control of peripheral finger temperature. Since basic individual differences in the ability to discriminate changes of peripheral finger temperature have been reported (e.g. Refs. [28,29]), field dependence–independence was also evaluated, hypothesizing that field-independent subjects could obtain better control in thermal BFB due to their greater ability in discriminating changes in exteroceptive feedback signals and or a greater ability in identifying relevant interoceptive cues in their internal environment.

Method

Subjects

Forty-four self-referred healthy subjects (25 females and 19 males), mean age 22.14 years (S.D. = 2.78), medication free, with no prior relaxation or BFB experience, volunteered for six sessions of thermal BFB training. All S’s were asked to refrain from caffeine for at least 2 h and from nicotine for at least 1 h before the beginning of each session.

Procedure

The training sessions were held twice a week, on fixed days and at the same time of the day, in a BFB laboratory of the Department of Psychology. The experiment started in February and finished in May. The room temperature was maintained at 23 ± 1 °C using two air conditioners positioned 2.5 m laterally to the subject, the first on the floor and the second on a wall perpendicular to the first. Airflows were parallel with respect to the subject’s position and did not affect the thermistors. Each session included the following conditions: (1) at least 15 min to adapt to the environment temperature; during the adaptation period the subject could move within the room, filled in the questionnaires, received detailed instructions about the procedure and finally sat in a reclining chair and had a thermistor attached; (2) 12 min of rest (REST), during which S’s maintained a comfortable position in a reclining chair while digital temperature was recorded; (3) a 12-min BFB training trial with the instruction to increase finger temperature; (4) a 12-min BFB training trial with the instruction to decrease finger temperature. Instructions given for the rest period were: “This period is for collecting recordings of your peripheral finger temperature in rest conditions. You have no task but to remain still, so please find a comfortable position so you will not feel the need to move during the next 12 min of recording”. Instructions given for the increase trial were: “During this trial you have to try to increase your finger temperature. You could be helped by the sound of the BFB machine. You will know that finger temperature increases from pulses that will be less frequent and lower in tone. Choose whatever strategy helps you best: You may create mental images of warmth (the sun over your hand, your hand in warm water and so on), or you may relax and clear all thoughts from your mind”. Instructions given for the decrease trial were: “During this trial you have to try to decrease your finger temperature. The sound of the BFB machine could help you: you will know that finger temperature decreases from the pulses which will become higher and more frequent. Choose whatever strategy helps you best, for example mental images of coldness (e.g. your hand in cold water and so on) or of situations in which you feel tense or upset”.

The order of the BFB training instructions (increase or decrease temperature) was alternated across sessions and balanced across S’s. REST and BFB training trials were separated by 3-min intervals during which S’s were allowed to change position and to ask questions. The third minute of this period was used to establish the reference value for the subsequent feedback trial.

A thermal BFB instrument (SATEM PT 201) interfaced to a personal computer through an optically isolated board (SATEM PT 411) was used for recording temperature during each session. The sensor (a thermocouple) was buffered with cotton wool and secured with a Velcro band to the palmar surface of the index finger of the subject’s dominant hand. Temperature was sampled every 100 ms.

During the BFB training trials, a pulse tone analogic FB was provided through a small loudspeaker placed behind the subject’s head. The pulse tone frequency decreased proportionally to the increase of temperature.

Trait anxiety was assessed through the State–Trait Anxiety Inventory [30], while LC was assessed through the Rotter Scale [31]. In order to assess field dependence–independence, at the beginning of the last session, the experimenter administered the individual form of the Embedded Figures Test [32] and recorded the time required by the subject to recognize each embedded figure. Tests for assessing psycho-
logical variables were given at the beginning of the second (STAI), third (Rotter Scale) and fourth (EFT) sessions.

Results

For each session, mean peripheral skin temperature continuously recorded during the 1st, 4th and 12th minute of each trial (REST, INCREase, DECREase) were computed and submitted to a $6 \times 3 \times 3$ repeated-measures ANOVA, factors being Sessions (1st to 6th), Conditions (REST, INCR, DECR) and Minutes (1ST, 4TH, 12TH). Results showed a significant two-way interaction [$F(4,128)=45.3; P<.001$] and a marginally significant three-way interaction [$F(20,640)=1.4; P<.09$]. Post hoc tests comparing means obtained in the significant two-way interaction showed that during rest and during the increase condition, there were significant increases of finger temperature from the first to the last minute. These increases were bigger in the rest condition than in the increase condition. Differences between the first and last minute in the decrease condition were not significant. The results are reported in Fig. 1.

Table 1

<table>
<thead>
<tr>
<th>Session</th>
<th>ANOVA</th>
<th>$F$</th>
<th>$P$</th>
</tr>
</thead>
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<td>.907</td>
</tr>
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<td></td>
<td>Minute</td>
<td>10.22</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
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<td>&lt;.001</td>
</tr>
<tr>
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<td>Condition</td>
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<td>.024</td>
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<tr>
<td></td>
<td>Minute</td>
<td>19.01</td>
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<td></td>
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<td>&lt;.001</td>
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<tr>
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<td>Condition</td>
<td>3.51</td>
<td>.034</td>
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<tr>
<td></td>
<td>Minute</td>
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<tr>
<td></td>
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<td>22.11</td>
<td>&lt;.001</td>
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<tr>
<td>4</td>
<td>Condition</td>
<td>2.58</td>
<td>.08</td>
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<tr>
<td></td>
<td>Minute</td>
<td>8.63</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
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<td>16.95</td>
<td>&lt;.001</td>
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<tr>
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<td>Condition</td>
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<td>.006</td>
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<td></td>
<td>Minute</td>
<td>15.73</td>
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<td></td>
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<td>Condition</td>
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<tr>
<td></td>
<td>Minute</td>
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<td>.003</td>
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<tr>
<td></td>
<td>Condition x Minute</td>
<td>10.60</td>
<td>&lt;.001</td>
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Table 2

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<tr>
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<th>Condition x Minute</th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
<th>Condition 4</th>
<th>Condition 5</th>
<th>Condition 6</th>
<th>Mean</th>
<th>S.D.</th>
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<td>1.6*</td>
<td>2.1*</td>
<td>3.1*</td>
<td>1.8*</td>
<td>2.6*</td>
<td>1.0*</td>
<td>2.03</td>
<td>0.74</td>
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<td>0.3</td>
<td>0.4</td>
<td>0.6*</td>
<td>0.3</td>
<td>0.7*</td>
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<td>0.50</td>
<td>0.19</td>
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<tr>
<td>DECR</td>
<td>-0.1</td>
<td>-0.3</td>
<td>-1.7*</td>
<td>-0.4*</td>
<td>-0.3</td>
<td>-0.6*</td>
<td>-0.57</td>
<td>0.58</td>
<td></td>
</tr>
</tbody>
</table>

* $P<.01$ at the Duncan test.
INCR, DECR) and Minute (1ST, 4TH, 12TH). The results of the ANOVAs are summarized in Table 1.

Significant main effects for the Condition factor were present in the 2nd, 3rd, 5th and 6th sessions. Both the main effect for the Minute factor and the Condition × Minute interaction, indicating different trends of temperature changes across the conditions, were significant in all sessions.

Fig. 2. Gender (F, M) × Conditions (REST, INCR, DECR) × Minute (1ST, 4TH, 12TH) interaction in the 2nd and 6th sessions.
Duncan post hoc tests, used to compare differences in temperature changes achieved between the 1st and 12th minute, revealed that in the REST condition, the difference was significant in all sessions; significant temperature changes, consistent with the instructions, were present in the 3rd and 6th sessions; in the 4th session, the difference was significant only when S’s were instructed to decrease finger temperature and in the 5th session, it was significant during the INCR instruction. The magnitude of changes between the 12th and 1st minute of REST, INCR and DECR conditions across sessions are reported in Table 2.

When gender was considered as a grouping variable, results confirmed the effects already described in the general ANOVA and summarized in Table 1; furthermore, they revealed a significant main effect for GENDER in all sessions [F(1,43) values range from 5.07 in the 3rd session to 15.89 in the 1st session] and a significant Gender × Con-Condition × Minute interaction in the 2nd [F(4,344)=2.5; P < .05] and 6th [F(4,344)=2.8; P < .05] sessions (see Fig. 2). Finger temperature means (M), standard deviations (S.D.) and coefficients of variation [CV, i.e. (S.D./M) × 100] in both males and females are shown in Table 3: The males’ mean temperature values were higher than the females’ during all the sessions. Analyses of the third-order interaction were conducted using Duncan post hoc tests and revealed that the expected difference between the 1st and 12th minute was significant during the DECR trial in the 2nd session and in the 6th session during both the INCR and the DECR trials in females. Males, on the contrary, did not show any significant temperature increase or decrease in any of the sessions.

The analysis was repeated considering three between-subjects factors defined on the basis of the individual differences assessed. S’s with scores below the 33rd percentile were assigned to a low group (LG), S’s with test scores equal or exceeding the 64th percentile were assigned to a high group (HG); S’s with test scores within the 33rd and the 64th percentile were assigned to an intermediate group (IG). The means of all three groups are reported in Table 4.

When subjects were grouped on the basis of the Rotter Scale or the STAI anxiety scores or on the basis of the EFT

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Table 4
Mean scores (with S.D. in brackets) of anxiety (STAI), LC and EFT for the low (LG), intermediate (IG) and high (HG) groups. Groups are defined according to the distribution of scores for each variable considered

<table>
<thead>
<tr>
<th></th>
<th>LG</th>
<th>IG</th>
<th>HG</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAI</td>
<td>26.5 (3.5)</td>
<td>34.2 (2.4)</td>
<td>46 (6.6)</td>
</tr>
<tr>
<td>LC</td>
<td>7.6 (2.2)</td>
<td>11 (0)</td>
<td>15.5 (7.3)</td>
</tr>
<tr>
<td>EFT</td>
<td>9.8 (4)</td>
<td>20.6 (5.1)</td>
<td>50.7 (9.6)</td>
</tr>
</tbody>
</table>

scores, results showed no significant main effects and no significant interactions.

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**Discussion**

The literature on thermal BFB shows that normal subjects may learn to voluntarily increase or decrease their peripheral temperature according to instructions. The present investigation replicated these results, confirming that normal subjects, with no prior experience in relaxation or BFB training, can learn to bidirectionally control their peripheral skin temperature through a brief thermal BFB training. The omnibus analysis, considering sessions, instructions and minute as factors, showed only a marginally significant third-order interaction. Learning to control finger temperature (as indicated by changes of temperature from the 1st to the 12th minute of the training trials consistent with the training instructions) was not statistically different across sessions. The absence of this statistical significance may depend on two nonalternative reasons. First, most of the variance in the analysis is explained by the difference between temperature recorded at the 1st and 12th minute of rest. This difference is relatively constant across sessions greater than the one voluntarily produced during training trials. Furthermore, peripheral temperature, as most psychophysiological variables, has a characteristically low reliability. >Pearson correlation coefficients computed on mean temperatures at the 1st minute of the six sessions were always very small, ranging from r = .22 (1st session vs. 5th session) to r = .65 (5th session vs. 6th session). All correlation coefficients are reported in Table 5.

For these reasons, six separate analyses of variance were conducted comparing temperature changes according to instructions within each session. These analyses showed
that some control on peripheral temperature is already present in the third session. However, it seems that a clear bidirectional control was established only in the 6th session.

The magnitude of the voluntary changes are small, even if they are similar to those reported by Freedman et al. [13,14]. The small magnitude of voluntary changes obtained in the present study might depend on the length of the training trials (12 min). Contrary to this explanation are some results from other studies indicating increases of finger temperature during BFB trials of 15 min or less [13,15,16] and a lack of effects with trial lengths of 24 min or more [35,36]. The small increases obtained in the present study could be due to the subjects who did not make up a clinical sample.

The present study was also aimed at investigating the possibility that individual and procedural variables could affect the ability to learn the bidirectional control of peripheral temperature and the magnitude of changes voluntarily produced through BFB training. Among the individual variables considered (gender and test scores in trait anxiety, LC and field dependence) gender was the only one to show significant effects. Results indicate that only female subjects were able to voluntarily control their peripheral skin temperature. The main effect of gender (males show higher temperature than females) and the second-order interaction (Gender × Condition × Minute) could indicate the presence of a ceiling effect for males as reported by other investigators (e.g. Refs. [4,15]). However, the present results do not entirely support this conclusion because males did not perform better in the decrease trial, as one would expect if the ceiling hypothesis was true. Since females perform better than males in both conditions (increase and decrease), we suggest that they have a greater ability to learn voluntary control over their peripheral temperature through BFB. Females learning probably benefits from greater mobility or variability of peripheral vessels, as indicated in our sample by a higher coefficient of variation of their peripheral temperature (see “CV” row of Table 3); greater variability has also been reported by Ray and Lamb [27] who found that males were less responsive to seasonal changes.

Concerning personal characteristics, the results of the present study fail to replicate those of Keefe and Gardner [16] and Surwit and Fenton [17] who found a positive relationship between trait anxiety and the ability to learn peripheral temperature control through BFB. This negative finding is not due to a reduced range of variability of scores in our sample, nor to low mean scores on the STAI questionnaire reported by the highly anxious subjects. Like anxiety scores, both LC and the field dependence-independence scores failed to show any relationship with voluntary control of peripheral finger temperature. This finding is consistent with the results of Stoffler et al. [33] who found that it was impossible to establish any difference between internals and externals in the ability to voluntarily control skin temperature. It is possible that consistency between LC and field dependence may be necessary in order to demonstrate individual differences in the ability to control peripheral temperature, as was found for electrodermal BFB [34]. In the present study, subjects with consistent profiles (i.e. internal and field independent or external and field dependent) were too few (n = 4 in each group) to allow any comparison.

The most relevant finding in the present study is that during the rest condition, there are constant increases in peripheral skin temperature, the magnitude of which is bigger than the changes obtained in the presence of FB-assisted instruction to increase finger temperature. Although, to our knowledge, no methodological study has directly investigated this issue, similar results have been reported by other investigators. Freedman et al. [14] recorded a mean increase of 0.3 °C during a 3-min rest, while the mean increase during FB trials (with respect to REST) was −1.1 °C. Kappes [22] and Montgomery [23] have reported similar results. During EMG BFB training, Keefe [15] recorded EMG and finger temperature; results showed that while EMG decreased only when feedback was provided, finger temperature increased both in the presence of EMG feedback (BFB trials) and in its absence (baseline sessions). Data reported by Boudewyns [37] also indirectly indicate a similar increase of temperature during rest periods. The author described a bimodal distribution of finger temperature in a 30-min rest session. Comparing distribution of mean finger temperatures computed from the first 5 min of rest to the last 5 min, the percentage of subjects with high temperatures (e.g. ranging from 29 °C to 37 °C) increases from 68% to 80%.

It might be helpful in clinical work to know that rest alone leads to significant spontaneous increases in finger temperature, greater than those obtained through BFB. BFB clinicians should be aware that, especially at the beginning of BFB training, when they want to foster learning of hand warming with few error signals, they should limit the duration of the rest period and make sure that the patient is active during the period of adaptation to the temperature of the room environment. This could increase the patients’ self-efficacy on their ability to learn the target behavior. On the other hand, when they want to test the patient or to rigorously assess the ability to increase peripheral temperature, the training session should be preceded by an adequate period (at least 12 min) of passive rest, in order to be sure that increases in finger temperature detected by the BFB instruments are due to the subjects’ ability to voluntarily determine hand warming and not to spontaneous fluctuations of their peripheral temperature due to rest alone.

References


