ical practice during the learning of a barrier task. Both immediate transfer and 48-hour retention effects were tested. In the immediate-transfer situation, the results revealed a significant main effect for group, with the effect primarily due to the poor performance of the videotape feedback group. The same effect also approached significance after the 48-hour retention period. Follow-up analysis revealed significant differences between transfer and retention periods within all conditions except modeling. Based on these results, the authors reached several conclusions and noted, "it seems to us that these results may call into question the long-held view that KR is the most potent variable for the learning of a motor skill."

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Digest Compilers, Volume 8

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JOURNAL OF SPORT PSYCHOLOGY, 1986, 8, 283-303

Multimodal Effects of Electromyographic Biofeedback: Looking at Children's Ability to Control Precompetitive Anxiety

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This study assessed the multimodal effects of electromyographic biofeedback on highly trait-anxious subjects, boys who scored in the upper quartile of the Sport Competition Anxiety Test (SCAT). Subjects participated in a bogus sport competitive tournament and participated individually in six laboratory sessions that consisted of a practice session and five matches. Each session comprised an adaptation period and three games separated by three rest periods. Biofeedback or placebo condition was administered during the rest periods. Frontalis EMG, heart rate, and respiratory rate were measured at the end of a rest period and immediately before every game (i.e., stress periods). State anxiety (STAIC; Spielberger, Gorsuch, & Lushene, 1970) was measured before every game, and game performance was also recorded. Results from a MANOVA combining the three physiological variables revealed significant variations between rest and stress periods but no significant group differences. Results from univariate repeated measures ANCOVAs on all dependent variables revealed that the biofeedback group was superior to the placebo group in reducing frontalis EMG both during rest periods and in the general competitive setting. Results support the specificity of single-system biofeedback training and are discussed in light of the discriminative/motor skills model and the trophotropic rebiasing model.

Each year, more than 20 million youngsters are involved in organized sports in North America (Roberts, 1984). Such participation is not taken lightly. Indeed, young athletes are often seen raging after defeat or crying from joy after victory. These observations are corroborated by much research which reveals that sport may represent one of the (if not the) most important activities for young people (see Veroff, 1969). For instance, in a recent study Duda (1981) reported that youth sport participants value success in sport more than success in school.

Although ascribing such a high value to sport may enable its participants to experience fun and excitement, it may also evoke anxiety and distress. Ac-

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cording to Martens' (1977) model of competitive stress, the more important and uncertain the sporting outcome, the more one experiences competitive anxiety. In line with this reasoning, Coddington (1972) reported that the possibility of failing to make a sport team is perceived as stressful as would be the death of a close friend. Thus sport can represent an important source of stress and tension. In addition, participants who have high levels of sport competition trait anxiety, the tendency to experience anxiety in sport competitive situations, should be more likely to experience higher levels of anxiety under such situations than those having lower trait anxiety (Martens, 1977). Thus, while some athletes will undoubtedly experience the stress of competition as challenging, others will experience competition as stressful and anxiety-provoking (Passer, 1982, 1983; Scanlan & Lewthwaite, 1984; Scanlan, Lewthwaite, & Jackson, 1984; Scanlan & Passer, 1978, 1979; Simon & Martens, 1979).

High levels of anxiety can be detrimental to motor learning, performance, and participation (e.g., Martens, 1977). Furthermore, anxiety is unpleasant and can cause various stress-related disorders (e.g., insomnia, headaches, lower back pain) when experienced frequently (Stoyva & Budzynski, 1974). Considering that these experiences are indeed frequent within youth sports, and considering that the developmental processes—crucial at that age—may be negatively influenced, this phenomenon clearly warrants the close attention of sport psychologists. One way to help young athletes reduce competitive anxiety is by teaching them stress-coping strategies such as relaxation.

Among the relaxation techniques documented to help control anxiety, EMG biofeedback has in the last 10 years attracted the attention of concerned experimental and clinical psychologists. Budzynski and Stoyva (1969; Stoyva & Budzynski, 1974) have been major instigators for the rapidly growing interest in EMG biofeedback. These authors claim that learning to relax the frontalis muscle by means of moment-to-moment feedback of one's level of muscle activity (EMG biofeedback) is a reliable method for achieving rapid and deep muscle relaxation. They hypothesize that EMG biofeedback training of a specific muscle group will produce a specific relaxation of this target muscle group. Furthermore, with training, a generalization of relaxation to other (untrained) muscle groups (within-modality generalization) and to other physiological correlates of stress (cross-modality generalization) should occur.

Budzynski (1977) and Stoyva (1977) explain the effects of EMG biofeedback in light of Gellhorn and Kiely's (1972) trophotropic rebiasing model (Fridlund, Fowler, & Pritchard, 1980). Budzynski and Stoyva postulate that the reduction in EMG activity reduces proprioceptive inputs to the hypothalamic reticular system. This promotes a shift toward the trophotropic system (parasympathetic activation) resulting in generalized arousal reduction of both the somatic and autonomic system (Stoyva, 1977). In other words, they assert that skeletal muscle tonus influences the central and the autonomic nervous systems, resulting in cross-modality relaxation.

The striated musculature proprioceptive inputs are deemed important because they account for a significant portion (approximately 50%) of the total body mass and play a key role in behavior. Among the different muscle groups, the frontalis has been the major target muscle in studies verifying the relaxing effects of biofeedback, namely because it is one of the most difficult muscles to deeply relax voluntarily (Balshan, 1962), it appears to be somewhat correlated with psychological measures of anxiety (e.g., Smith, 1973), and for measurement purposes it seems less affected by posture and gravity than other muscles (Coursey, 1975).

While the trophotropic model has received much attention because of its obvious clinical implications, another competitive model, the discriminative/motor skills model (e.g., Alexander, 1975; Johnston, 1977) has also been formulated. This model predicts a specific or discriminative relaxation response of the target modality under biofeedback training. Proponents hypothesize that subjects' relaxation response will become even more specific as a function of training (e.g., lower correlations between EMG measures and other stress-related variables). The discriminative/motor skills model also posits that during biofeedback, response control is occurring along the pyramidal and extrapyramidal channels and that the target muscle response would be phasic (rapid, temporally uncorrelated changes) due to its highly discriminated motor response. Finally, the model assumes that the frontalis response may be comparable to an instrumental response with respect to the other variables whereby the specific target muscle's response would differentiate more as a function of training when compared with other "untrained" muscles.

Reviews of the empirical evidence reveal that EMG biofeedback is an efficient means for relaxing the target muscle (Alexander & Smith, 1979; Blais & Orlick, 1977; Burish, 1981; Silver & Blanchard, 1978; Surwit & Keefe, 1978; Tarler-Benlolo, 1978). However, there is no conclusive evidence to support the notion that EMG biofeedback, when compared to a placebo or a control group, will (a) relax other untrained muscles (within-modality effect), (b) reduce general autonomic arousal, (c) increase subjective reports of relaxation and decrease self-reports of anxiety, and (d) be more efficient than other relaxation techniques.

In a recent review of the literature, Qualls and Sheehan (1981) present evidence that concurs with these latter observations with the exception of the cross-modality effect. They contend that more recent studies demonstrate "fairly substantial cross-modality effects during EMG biofeedback" (p. 30). However, this conclusion in support of the trophotropic rebiasing model is not shared by Burish, Hendrix, and Frost (1981) or by Carlson, Basilio, and Heaukulani (1983). Thus, the assumptions pertinent to EMG biofeedback's stress-reducing effectiveness (e.g., Stoyva & Budzynski, 1974) still remain to be demonstrated.

Only three published studies in the sports domain have addressed the issue of biofeedback's stress-reducing effects. In two studies by DeWitt (1980), selected athletes received a combination of EMG (frontalis, masseter, and/or trapezius) biofeedback and a combination of cognitive and behavioral techniques including mental rehearsal, systematic desensitization, and progressive relaxation. DeWitt (1980) reports in his first study (single group pretest-posttest design) that the six selected football players significantly reduced their EMG (exact muscle not specified) and improved in performance. DeWitt reported similar results in a second study with basketball players, in which a control group was added. He noted further that his biofeedback subjects also showed greater decreases in heart rate when compared to a control group. In the last study, Griffiths, Steel, Vaccaro, and Karpman (1981) reported that scuba diving students having a combination of frontalis EMG biofeedback and relaxation training reduced their state anxiety more than control subjects. No differences were found on indices of frontalis EMG, heart rate, respiratory rate, hand temperature, trait anxiety, and performance. The effect of EMG biofeedback is difficult to evaluate in such studies due to the fact that the biofeedback treatment was combined with other stress-coping strategies.

The relation between EMG biofeedback and performance enhancement under stress has also received inconclusive evaluations (e.g., Burish et al., 1981; Lawrence & Johnson, 1977). To that effect, Lawrence and Johnson note the apparent lack of support for reliable relations between internal events and performance. A lack of theory on the role of biofeedback on performance enhancement is also evident.

With respect to the generalizability of results, the majority of empirical studies in the literature have focused on adult populations. Presently, few controlled studies (none published) can inform us on the efficiency of EMG biofeedback as a relaxation or anxiety control technique for youngsters. Blais (1979) did suggest, however, that biofeedback's unique features for learning muscle relaxation such as providing augmented, simultaneous, and understandable feedback could be particularly helpful for youngsters, assuming they deal better with concrete illustrations of tension. Furthermore, to the best of our knowledge, no study has investigated the effects of EMG biofeedback on reducing precompetitive anxiety under controlled competitive stress situations akin to those found in sport.

In summary, previous claims on the cross-modality effects of biofeedback at this point are empirically inconclusive. Furthermore, although we know very little on the cross-modality effects of EMG biofeedback for helping youngsters to cope with competitive stress, there are persistent commercial claims in amateur sport circles that it does help athletes cope better with stress and that it enhances performance.

In light of the above, the purpose of this study was to investigate the multimodal effects of EMG biofeedback on frontalis EMG, heart rate, respiratory rate, state anxiety, and motor performance under sport competitive stress situations with high sport competition trait-anxious youngsters. In line with both the trophotropic rebiasing model and the discriminative/motor skills model of biofeedback training, it was hypothesized that the EMG biofeedback condition would be more efficient in relaxing the target muscle than the placebo condition. Due to the inconclusiveness of previous findings on the cross-modality effect of EMG biofeedback, no hypothesis was emitted with respect to the other variables. The cross-modality effect was nevertheless verified via between-group analyses (MANOVA and ANCOVA) and within-group analyses (zero-order correlations).

Method

Subjects

Subjects in this study were boys 10 to 13 years of age. From a sample of 261 boys, 80 scored in the upper quartile of the SCAT norms (see Martens, 1977). This latter sample was then randomly divided in either a biofeedback subsample or a placebo subsample. Finally, 10 subjects were randomly selected from each subsample to participate in the study. Subjects averaged 11.7 years in age and had an average SCAT score of 24.6 (standard deviation = 2.2). No significant differences ($t < 1$) were found between the two groups on the SCAT. Parents of these boys completed a consent form and confirmed that their child was not taking any drugs and did not have any apparent physical or psychological problem.

Laboratory Setting

There were two rooms in the laboratory, a control room and a tournament room separated by a one-way mirror. Access to the control room was limited to the experimenter and the technician. It contained all the instruments necessary to record data, and to control the cameras and the monitor's display in the tournament room, as well as prerecorded dialogues on audiotapes, and the bogus opponent's timer.

The tournament room was an environment-controlled room arranged in such a way as to create a credible competitive environment. "Official" tournament posters, a scoreboard, and a contestants' position board were placed on the wall facing the subjects. Posters were also placed on the other walls and on the doors of the laboratory. The room was equipped with two remote-controlled cameras located at ceiling level, a microphone hanging from the ceiling, and a loudspeaker.

This room also contained an armchair equipped with two speakers that were connected either to the EMG biofeedback unit or to the white noise generator (model 15012 from Lafayette, set at 22 dB). On the left side of the armchair was the EMG biofeedback's unit positioned on a rotating chair. A stabilometer (model 3-15 from Marietta Apparatus) was situated three meters in front of the armchair. At a distance of one meter in front of the stabilometer was a table that held the subject's timer and error counter module. The opponent's timer was placed over the subject's timer. Next to the table was a 48 cm television monitor on a stand that was connected to the remote controlled cameras focusing on either the subject or the opponent's timer. A clock timer was located below the monitor to display elapsed times before playing and elapsed time of a game trial. Questionnaires were on a table to the right of the armchair.

Instruments

Physiological Measures. The EMG biofeedback unit model 401 C from Bio-Feedback Technology was used for the biofeedback treatment. The auditory feedback mode used was a "click" modulation (decreases in click frequency correspond to lowered EMG activity). Visual feedback was available through the unit's analog meter. EMG was recorded by means of the Time Period Integrater model BFT 215 C (Bio-Feedback Technology) connected to the biofeedback unit. EMG measures were averaged peak-to-peak microvoltage (p-p μV) values of EMG activity for determined sample times. Surface electrodes were set on the frontalis muscle in accordance with Kondo, Canter, and Bean (1977). The active and reference electrodes for EMG were placed on either side of the forehead (frontalis) at 2 cm above the eyelid. The ground electrode was placed equidistant from the two latter electrodes, which corresponded approximately to 2 cm above the nasion process. Skin resistance was verified before the sessions started, and the acceptable limit was established at less than 10,000K in Ohm count. The EMG unit was set on the 95-600 Hz bandpass in order to have a signal relatively free of artifact such as the EEG and the EKG. A "shorted test" was also conducted before the session started, and it showed a respectable level of "free air" artifact in both rooms for biofeedback training and EMG measurement.

Surface electrodes for heart rate measurements were placed in the "V-4" position in accordance with Cambridge (1971). The ground electrode was located on the xyphoid process, while the active and the reference electrodes were placed on the fifth intercostal space to the left midclavicular line and on the manubrium, respectively. A pneumograph model P 907 E/M was used for measuring respiratory rate. The bellow belt was placed around the chest between the ground and reference EKG electrodes (Huizinga, 1962). Recordings for both heart rate (bpm) and respiratory rate (cycles/min.) were made on a physiograph model DMP-4B by NARCO Bio-Systems.

Psychological Measures. Sport competition trait anxiety was measured by the SCAT (Martens, 1977). Precompetitive state anxiety was measured by the state anxiety form of the STAIC (form C-1). The two instruments have been previously found to show adequate levels of reliability and validity. For more information on the psychometric properties of these instruments, the reader is referred to Martens (1977).

Performance Measure. Performance was evaluated by time spent on balance on the stabilometer. Time was measured at the .001 second.

Procedures

The SCAT (Martens, 1977) was administered by the experimenter (first author) to 261 boys at a local boys club in Ottawa 1 month before actual experimentation began. The experimenter told the boys he was making a study on how boys of their age felt in general, and more specifically how they felt before competing in sports. He assured them their answers would be confidential. From those subjects, 20 were selected as indicated in the subjects section (see above).

The experimenter telephoned the 20 selected boys and told them they were selected from a large number of boys to represent their region in an interprovincial balance competition, "The First Annual Motor Performance Tournament." Subjects were also told it was a special type of competition in which they would be competing against opponents through closed-circuit television. The experimenter added that he would coach them and at the same time study a new way to help athletes relax before competing. Actually, subjects were to participate in a bogus sport competitive tournament. The experimental setting (see above) was designed to create as much as possible a realistic competitive environment while keeping important situational variables constant across subjects.

Based on Martens' (1977) construct of sport competitive stress, the bogus tournament was designed to progressively increase the importance and uncertainty of outcomes toward the last match. Further, conditions such as opponent, audience, and success-failure were held constant for all subjects. Taped conversations between bogus characters (tournament judge, broadcasting technicians, and coaches) played through the laboratory speaker, special posters, and scoreboards were all used to increase the credibility of the setting.

The objective of each participant in the tournament was to defeat an opponent two out of three times to win a match and to achieve first place in a pyramidal tournament that consisted of five matches. Subjects came to the laboratory on six different days. These sessions were scheduled at the same time and were completed within a 2-week period. These laboratory sessions consisted of a practice session and five tournament matches. Each session comprised an adaptation period and three games separated by three rest periods. Biofeedback training and the placebo condition were administered only during the rest periods. At the end of the last session, subjects underwent a postexperiment interview before leaving.

Practice Session. Upon entering the laboratory on an individual basis, subjects were shown the control room. They were told the room was used by a technician to control the cameras and communication for the closed-circuit tournament and also to record how they reacted to the competition without disturbing them. Subjects were then brought to the tournament room. Electrodes and pneumograph were set and subjects sat in the armchair. They were told to relax as much as possible for 5 minutes. The experimenter left the room. Physiological measurements were taken at the last minute of this 5-minute adaptation period. Following this 5-minute period, the experimenter reentered the room and explained how to answer the STAIC C-1 (state anxiety).

After subjects completed the questionnaire, they listened to recorded instructions given by the director of the "First Annual Motor Performance Tournament." The voices of the director and of other bogus characters (technician, official, etc.) on other recorded tapes were those of male professional television and radio announcers. Information given by the director included goals of that particular type of competition as well as the general rules and procedures of the tournament. The general rules of the tournament were identical to the procedures suggested by Beeman and Humphrey (1960) for a pyramidal tournament, which was selected for its highly salient competitive structure.

Subjects had three 30-second trials on the stabilometer, separated by two rest periods of 5 minutes each. Subjects also had a 10-minute rest period after the third trial. Following each trial, the experimenter provided all subjects with feedback about their performance (i.e., time on balance) while guiding them back to the armchair.

During the first rest period, the experimenter told the subjects what they would be doing during rest periods—that they should try to relax as much as possible and that becoming aware of their forehead muscle tension may help them relax better, particularly before the competition. They were also told to try to relax and stay as calm as they could before competing.

In addition to this information, biofeedback subjects were told to listen to the clicks or to look at the analog meter of the biofeedback unit in order to get feedback of their forehead tension level. It was explained that as they hardened the forehead muscle, clicks would speed up and the needle would move toward the right side. They were also told that when they relaxed their forehead muscle, the clicks would slow down and the needle would fall to the left side of the meter toward the "O" reading. Meanwhile, subjects were told to practice contracting and relaxing their muscle while listening to the clicks or looking at the needle. Subjects were left free to choose the feedback modality (i.e., auditory or visual) they preferred. They were also told that as they learned to control the muscle, the machine would become more sensitive and they would have to relax much more in order to reduce the clicks or to lower the needle's reading. Subjects in both groups were told not to concentrate too hard on trying to relax.

Subjects were then left alone in the tournament room for the rest period. The physiological variables were recorded during the last minute of the rest period. When the biofeedback subject's last minute EMG reading was lower than the first reading, the experimenter reentered the room and told the subject he was doing well. This feedback was also given to the yoked placebo subject at the same stage of the experimental procedure. All subjects at some point received positive feedback. Subjects then completed the STAIC C-1 and proceeded to the stabilometer. After the third rest period the experimenter reentered the room and removed the electrodes and pneumograph from the subject. Before leaving, subjects were asked not to mention to anybody, except their parents, their participation in the tournament.

Tournament Sessions. Relatively the same procedures were followed for the five tournament sessions except that subjects were now involved in competition. After the adaptation period, subjects heard through the room's speaker the recorded dialogues between different characters involved in the tournament (coach, official, technician) but located at the site of the other contestant. The experimenter, serving as a coach, also interacted with these characters.

The head official then announced the contestants' placement on the pyramidal structure (see Table 1 for subjects' starting position in all matches). He then announced that the game would start in 3 minutes. Meanwhile, the experimenter turned on the TV monitor and left the room. This large TV monitor was used to make salient the presence of an audience and especially what it was focusing on. Procedures involving the cameras and TV monitor were the same for all subjects. The camera zoomed in on the subject for 30 seconds, then zoomed in on the stabilometer. Physiological measures were recorded at the 3rd minute. The experimenter then reentered the room and asked subjects to answer the STAIC C-1. These physiological and psychological data will be referred to as the stress period data.

After completing the questionnaire, the official came "on the air" and announced there was 1 minute left before game time. At that moment the subject could leave the armchair to take his starting position on the stabilometer. After the minute was over the official asked if everybody was ready and proceeded to give the starting commands. During the game, the opponent's timer readout was controlled by the technician in the control room. The win-loss ratios were predetermined (see Table 1), and differences of performance and final results were kept at approximately 1 second so that subjects would perceive similar ability between contestants. Following the game, the judge announced the result, commented on the importance of the following game or match, and congratulated the winner.

Every game was followed by a rest period, during which the experimenter closed the TV monitor, gave the same instructions as in the practice session for the rest period, and left the room. Physiological measurements were taken during the last minute of relaxation and these measurements will be identified as those taken during the rest periods. After these measures were recorded, the experimenter reentered the room, gave positive qualitative feedback (if applicable) on the subject's attempt to relax the frontalis, and turned on the TV monitor. The procedures were then repeated for games 2 and 3 as well as for the following matches. Subjects won the first match, lost the second, and then won the last three matches, and therefore the tournament.

Table 1

Corresponding Level of Competition With Subject's Bogus Opponent's Number and Controlled Win-Loss Outcome According to Game and Match Results

Opponent's number	Match 1 2	Match 2 3	Match 3 4	Match 4 3	Match 5 6
Pyramidal level	I	I	II	II	II
Game 1 win-loss	W	L	W	L	L
Game 2 win-loss	L	W	L	W	W
Game 3 win-loss	W	L	W	W	W
Match result win-loss	W	L	W	W	W

In summary, subjects in both conditions were subjected to exactly the same competitive environment. The only difference in procedure between the placebo and the biofeedback subjects took place in the relaxation task wherein biofeedback subjects had a biofeedback treatment and placebo subjects were listening to white noise.

At the end of the last session, subjects answered the SCAT. The experimenter also interviewed them in order to assess more fully the credibility of the bogus tournament. Subjects were then asked to promise not to mention anything about the experiment to any of their friends. No debriefing took place. In line with Scanlan (1975), it was felt more important to let subjects leave the laboratory with positive feelings about their accomplishments than to explain the actual procedures of the experiment.

Results: Overview

Results are presented according to type of variables (i.e., physiological, psychological, and performance data). The physiological data were analyzed by multivariate and univariate analyses. In order to verify a cross-modality effect, a multivariate analysis was conducted combining the three physiological measures. The multivariate design was a 2 × 5 × 2 (groups × matches × stress/rest periods) with repeated measures on the last two factors. This 2 × 5 × 2 design was used to account for the physiological data recorded during stress periods (i.e., moments before playing) as well as during the rest periods (i.e., last minute of the relaxation period). It therefore presented an overall picture of subjects' physiological reactions to the general competitive setting while accounting for a stress/rest factor.

In addition, a series of univariate analyses were conducted on EMG, heart rate, and respiratory rate individually in order to test for the discriminative/motor skills model. First, the data were treated by a $2 \times 5 \times 2$ (groups × match × stress/rest periods) design through univariate analysis of covariance with repeated measures on the last two factors and using the baseline measure of the practice session as a constant covariate.[1] A second type of univariate analysis of covariance treated only the data recorded during stress periods. The statistical design was a $2 \times 5 \times 3$ (groups × matches × stress periods) with repeated measures on the last two factors. The last factor was also nested within the second factor. A third type of univariate analysis treated only the data recorded during rest periods. The statistical design was a $2 \times 5 \times 3$ (groups × matches × rest periods) similar to the latter design with the exception that the last factor consisted of the rest periods.

State anxiety and motor performance were recorded only three times within a given match and were therefore analyzed by the $2 \times 5 \times 3$ (groups × matches × stress periods) univariate design with repeated measures on the last two factors. The last factor was also nested within the second factor.

Finally, in order to test for a cross-modality effect, zero order correlations were conducted between frontalis EMG data and the other dependent variables across time. The alpha level of $p < .05$ was used for all statistical analyses.

Manipulation Checks

Verbal responses to the postexperiment interview suggest that subjects strongly believed the competition was real. None of them indicated any doubts about the credibility of the tournament; all found it to be fun and exciting. Behavioral indices during experimental sessions such as praying to win before playing, cursing the opponent after a loss, or crying from joy after winning the tournament also support results of the postexperiment interview. Furthermore, results presented below on EMG, heart rate, and state anxiety also corroborate the notion that competitive situations were indeed perceived and experienced as stressful.

Physiological Measures

Multivariate Analysis

The $2 \times 5 \times 2$ (groups × matches × stress/rest periods) multivariate analysis conducted on the data revealed that the group main effect was nonsignificant ($p < .05$). However, a significant multivariate main effect was found on the matches factor, $F(12, 7) = 3.53, p < .052$, whereby univariate significant variations were evidenced for EMG, $F(4, 15) = 3.57, p < .031$, and respiratory rate, $F(4, 15) = 3.59, p < .03$. Averages in EMG gradually declined from match 1 to match 5. Means were, respectively, 25.3, 21.3, 20.25, 19.5, and 19.7 p-p μV/min. On the other hand, the average respiratory rates from match 1 to match 5 were, respectively, 19.55, 17.9, 18.39, 18.09, and 19.31 cycles/min. Newman-Keuls post hoc analyses revealed that respiratory rate was higher in the first and last match than the other matches ($p < .05$). Heart rate did not vary significantly across matches.

A significant multivariate main effect was also found on the stress/rest factor, $F(3, 16) = 3.95, p < .028$, whereby significant differences were evidenced for EMG, $F(1, 18) = 7.04, p < .016$, and heart rate, $F(1, 18) = 8.13, p < .011$. Greater activation was measured for both variables during stress periods as compared with the rest periods. The EMG p-p μV/min means for stress and rest periods were, respectively, 24.3 and 18.14 whereas heart rate means were, respectively, 83.63 and 81.28 bpm. All multivariate interactions were nonsignificant.

Univariate Analyses

EMG Data. Results from the $2 \times 5 \times 2$ (groups × matches × stress/rest periods) univariate analysis of covariance revealed a significant group main effect, $F(1, 17) = 7.15, p < .016$. Considering the combined data from stress and rest periods, the biofeedback group ($M = 15.49$ p-p μV/min) demonstrated significantly lower levels of EMG than the placebo group ($M = 26.95$ p-p μV/min). Furthermore, as previously reported, the stress/rest factor was also significant, $F(1, 18) = 7.04, p < .016$. A significant match × stress/rest periods interaction, $F(4, 72) = 2.62, p < .042$, was also evidenced. Simple-effects tests of the interaction (Dixon, 1983) revealed that the average EMG for both groups was greater during stress periods than rest periods, namely in the first match ($M = 30.83$ and 19.78 p-p μ V/min), $F(1, 18) = 15.41, p < .001$, and in the last match ($M = 23.55$ and 15.87 p-p μV/min), $F(1, 18) = 8.94, p < .008$. No significant differences were observed in matches 2, 3, and 4. All other main effects and interactions were nonsignificant.

Results from the $2 \times 5 \times 3$ (groups × matches × stress periods) analysis of stress periods revealed a significant-matches main effect, $F(4, 72) = 4.10$, $p < .005$. Newman-Keuls analyses revealed that EMG in match 1 was significantly higher than in any other matches ($p < .05$). Average EMG are, respectively, 30.83, 24.33, 20.94, 21.85, and 23.54 p-p μV/min. Furthermore, the biofeedback group had marginally lower EMG ($M = 19.46$ p-p μV/min) than the placebo group ($M = 29.13$ p-p μV/min), $F(1, 17) = 3.03, p < .10$.

The same analysis also revealed a significant stress periods × group interaction, $F(10, 180) = 2.16, p < .022$ (see Figure 1). Simple-effects tests of the interaction revealed at match 1 a stress periods × group interaction, $F(2, 36) = 3.82, p < .031$, whereby at game 3 the biofeedback group ($M = 22.57$ p-p μV/min) had marginally lower EMG than the placebo group ($M = 38.57$ p-p μV/min), $F(1, 17) = 3.82, p < .067$. In match 2, a stress-periods main effect was revealed, $F(2, 36) = 3.31, p < .048$, whereby EMG before games 1 and 3 was greater than before game 2. In match 3, a significant group effect, $F(1, 17) = 5.60, p < .03$, was found, the biofeedback group ($M = 15.27$ p-p μV/min) showing lower EMG than the placebo group ($M = 26.61$ p-p μV/min). No significant effects or interaction was found in match 4. In match 5, however, the biofeedback group ($M = 18.11$ p-p μV/min) had marginally lower EMG than the placebo group ($M = 28.98$ p-p μV/min), $F(1, 17) = 3.24, p < .09$. Further-

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[1] Because the data were possibly dependent across sessions, it seemed more appropriate to use a constant covariate than a changing one. A covariate was used for the univariate analyses in order to reduce error and to account for possible group differences at baseline. Except for respiratory rate, no significant differences between groups were found at baseline on any of the dependent variables in this study. A covariate was not used in the multivariate design because not enough degrees of freedom were available to compute an exact probability.

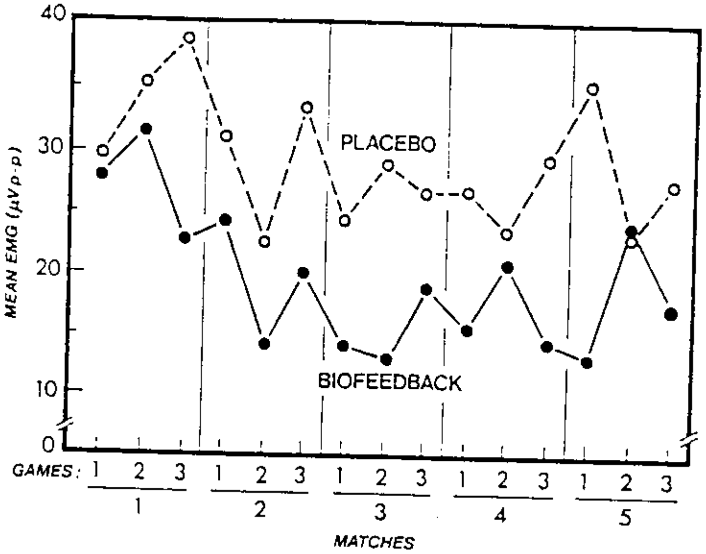

Figure 1 — Stress periods × group interaction of EMG frontalis measures taken during the stress periods (games) across matches.

more, a significant stress periods × group interaction was found in match 5, $F(2, 36) = 4.81$, $p < .014$, whereby the biofeedback group ($M = 13.21$ p-p μV/min) had lower EMG than the placebo ($M = 35.63$ p-p μV/min) group before game 1, $F(1, 17) = 12.58$, $p < .003$. In summary, this significant two-way interaction on the stress data indicates that biofeedback subjects demonstrated lower EMG under specific types of stressful games (e.g., game 1 of match 5) and matches (e.g., match 3).

Results from the 2 × 5 × 3 (groups × matches × rest periods) analysis on rest periods revealed that the biofeedback group had lower EMG (11.51 p-p μV/min) than the placebo group (24.77 p-p μV/min) during rest periods, $F(1, 17) = 9.36$, $p < .007$. All other main effects and interactions were nonsignificant.

Heart Rate Data. Analysis of the heart rate by the 2 × 5 × 2 (groups × matches × stress/rest) statistical design revealed a significant stress/rest main effect as was reported from the multivariate analysis. All other main effects and interactions were nonsignificant. Results of the 2 × 5 × 3 analyses treating stress periods and rest periods separately did not reveal any significant main effects or interactions.

Respiratory Rate Data. A significant-matches main effect, $F(4, 72) = 5.19$, $p < .001$, was revealed from the 2 × 5 × 2 (groups × matches × stress/rest period) analysis. As reported previously, higher respiratory rates were observed in matches 1 and 5. Similar matches main effects were found in the 2 × 5 × 3 analyses treating stress periods, $F(4, 72) = 4.89$, $p < .002$, and rest periods, $F(4, 72) = 2.72$, $p < .036$, separately. Looking at only the stress periods data, Newman-Keuls' analyses revealed that respiratory rate was significantly higher ($p < .05$) in the first and last match when compared with matches 2 and 4 ($M = 19.32, 17.53, 18.42, 17.60, 19.27$ cycles/min.). Post hoc analyses of respiratory rate during rest periods revealed higher activation ($p < .05$) in match 1 when compared to match 2 ($M = 19.78, 18.27$ cycles/min.). All other main effects and interactions were nonsignificant.

Psychological Measures

Univariate analyses were conducted on two self-report anxiety measures, one measuring state anxiety and the other measuring sport competitive trait anxiety.

State Anxiety Data

State anxiety was measured during stress periods only. The 2 × 5 × 3 (groups × matches × stress periods) analysis revealed a significant stress–periods effect, $F(10, 180) = 3.97$, $p < .0001$. Simple-effects analyses were conducted in order to interpret this repeated measure factor which is nested within each match. The analyses revealed significant variations in state anxiety within match 1, $F(2, 36) = 3.36$, $p < .046$, match 2 $F(2, 36) = 4.37$, $p < .02$, match 3, $F(2, 36) = 5.61$, $p < .008$, and match 4, $F(2, 36) = 5.16$, $p < .011$. Figure 2 illustrates the marked variations for both groups across games and matches. Of interest is the finding that changes in state anxiety systematically vary with previous objective success-failure. Significant changes between games and matches are presented in Figure 2.

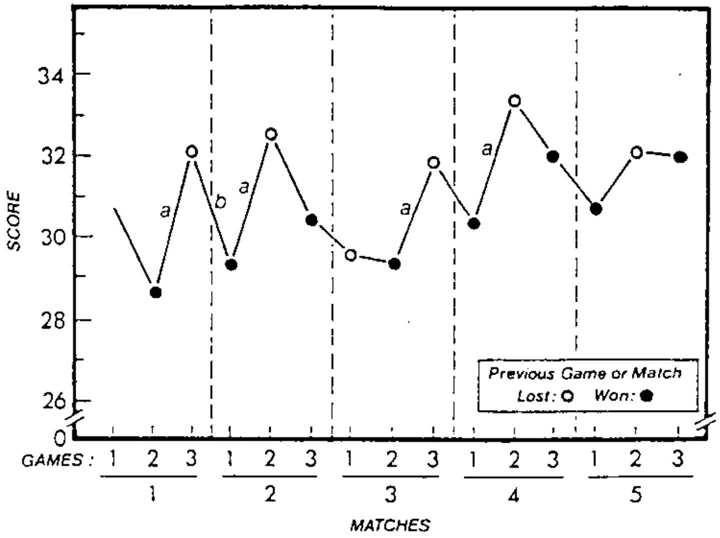

Figure 2 — Mean score of state anxiety as assessed by the STAIC FORM C-1 for the placebo and the biofeedback groups combined across the five matches with reference to previous game or match outcome. a = significant post hoc comparison (Newman-Keuls, $p < .05$) between games within matches; b = significant a priori contrast ($p < .05$).

In order to test the impact of previous objective success-failure, an a priori cell comparison was conducted whereby state anxiety data taken when subjects had previously won a game or match were combined and compared with state anxiety data taken when subjects had previously lost a game or match. Results of the analysis revealed a significant difference as a function of previous success ($M = 30.34$) and failure ($M = 31.96$), $F(1, 18) = 8.24$, $p < .01$.

Sport Competition Trait Anxiety

Sport competition trait anxiety was measured before and after the tournament. The data were analyzed by a one-way analysis of covariance in which the pretest measure was used as the covariate. Results of the analyses indicated no significant differences between groups on the posttest measures.

Performance Measure

Time on balance was analyzed by the 2 × 5 × 3 (groups × matches × stress periods) analysis of covariance with repeated measures on the last two factors. The last factor was also nested within the second factor. Results revealed that both groups demonstrated significant improvement in time on balance across games and matches as revealed by a matches main effect, $F(4, 72) = 9.71$, $p < .0001$, and a matches × trials interaction, $F(10, 180) = 3.88$, $p < .0001$. Performance average across matches were, respectively, 4.44, 5.81, 6.91, 7.03, and 7.66 seconds.

Changes in Correlations

Correlations between EMG data and the other dependent variables were computed in order to observe if frontalis EMG became progressively more related with the other parameters of arousal as subjects received more biofeedback training as predicted by the trophotropic rebiasing model. Table 2 displays averaged correlations for the first and last match for the biofeedback group and the placebo group.[2] Correlations equal and above .54 ($n = 10$) are significant at $p < .05$. Due to the small number of subjects, however, these analyses must be regarded with caution.

From the 15 situations in which data were collected in the stress periods (3 in each match), some significant correlation coefficients were found. Table 2 presents the number of significant correlations that were found as well as the range of these coefficients. In general, few coefficients were significant. The greatest number of significant correlations found was with the biofeedback group for correlations between EMG and heart rate and between EMG and performance.

Looking at the stress periods data of the biofeedback group, frontalis EMG tended to become more positively correlated with heart rate and state anxiety as well as more negatively correlated with performance over time. For the placebo group, however, EMG tended to become more negatively correlated with the other variables (inverse for performance). For both groups, covariation between EMG and respiratory rate appeared to decrease in magnitude gradually across the stress periods. However, none of the differences in correlations within or between groups were significant.

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[2] The full correlation matrices are available through the first author.

Table 2

Correlations Between EMG Frontalis and Heart Rate, Respiratory Rate, State Anxiety, and Performance Across Time (Match 1–Match 5)

		Stress Periods Data			
Variables	Group	Match 1[a]	Match 5[a]	# of Signif. corr.[b]	Range
EMG + HR	Biofeedback	0.36	0.45	5/15	−.22, .73
	Placebo	0.23	−0.21	1/15	−.34, .61
EMG + RR	Biofeedback	0.44	0.1	2/15	−.15, .69
	Placebo	−0.11	−0.06	1/15	−.41, .81
EMG + ANX	Biofeedback	−0.26	0.27	1/15	−.58, .49
	Placebo	0.06	−0.4	2/15	−.60, .24
EMG + PERF	Biofeedback	−0.26	−0.38	4/15	−.62, .14
	Placebo	−0.05	0.04	0/15	−.45, .40

[a] Averaged correlations of game 1, 2, 3 within specified match.
[b] $p < .05$
HR = heart rate; RR = respiratory rate; ANX = state anxiety; PERF = performance.

Discussion

The purpose of this study was to investigate the multimodal effects of EMG biofeedback on frontalis EMG, heart rate, respiratory rate, state anxiety, and motor performance under sport competitive stress situations with high sport competition trait-anxious youngsters. It was hypothesized that the EMG biofeedback condition would be more efficient than the placebo condition in relaxing the target muscle. The present findings support this hypothesis and concur with previous studies showing that a single-system biofeedback (i.e., frontalis) promotes specific relaxation to the target modality (Alexander & Smith, 1979; Blais & Orlick, 1977; Burish, 1981; Silver & Blanchard, 1978; Surwit & Keefe, 1978; Tarler-Benlolo, 1978) and does not demonstrate a cross-modality effect on heart rate, respiratory rate, and state anxiety when compared with a placebo control group (e.g., Alexander, White, & Wallace, 1977; Burish et al., 1981; Davis, 1980). Therefore, a first important finding of this study is that biofeedback training does produce localized muscle relaxation relative to a placebo group.

Some authors (Alexander et al., 1977; Davis, 1980) have argued that biofeedback subjects achieve greater relaxation of their frontalis than control subjects because the task of these latter subjects is not very motivating compared to that of the biofeedback group. Alexander et al. proposed that to increase the motivational equivalence between the two groups, instructions to relax should be given periodically to subjects in the control group. Using such instructional sets, Alexander et al. (1977) and Davis (1980) found no significant difference between both groups. The present study also used such instructional sets but did find significant differences on the target modality. These findings thus support the role of biofeedback as opposed to instructional sets in leading to subjects' actual relaxation.

This study differs from other published studies on EMG biofeedback on the basis of its target population (high sport-competitive trait-anxious boys) and experimental context (simulated championship). This could also account for the differences in results with the Alexander et al. (1977) and Davis (1980) studies. All our subjects were high on sport competitive trait anxiety and were participating under competitive stressful situations akin to those found in sport. In the majority of controlled studies on relaxation techniques, however, "normal" adult subjects are used and the experimental conditions are also typically nonthreatening. A floor effect may be occurring in several of these studies (Burish et al., 1981). Having high sport-competitive trait-anxious boys involved in a highly important sport competition has permitted us to study the effects of biofeedback on higher levels of arousal and anxiety. The study of biofeedback's effects under stressful conditions is very pertinent and thus contributes to external validity because people usually want to learn to relax in order to better cope with stressful situations (Burish et al., 1981).

Though the present results concur with the majority of previous findings in support of a specificity effect, it should be noted that the methodology used provides a stringent test of the effect of EMG biofeedback. During the six experimental sessions, subjects were learning to relax in the midst of a so-called provincial tournament setting. The situation may be comparable to an on-site championship intervention. The high trait-anxious boys having biofeedback did nevertheless learn to significantly relax their frontalis; however, this did not promote a more generalized relaxation response.

Results on the EMG data point out that the biofeedback group showed lower levels of EMG during rest periods (i.e., at the end of biofeedback training without the feedback) and in the general competitive situation (i.e., combining both rest and stress periods data). Considering only the stress periods data, the biofeedback group had only marginally lower EMG than the placebo group. The significant stress periods × group interaction for this data, however, is quite interesting, showing that the biofeedback group was superior to the placebo group in reducing muscle tension under specific stressful situations (see Figure 1).

Simple-effects tests of this interaction revealed that during match 3 the biofeedback group was consistently superior to the placebo group in having lower EMG. As revealed in other analyses, match 3 is (relatively) the least stressful match. In that respect, it is interesting to note that when the average EMG level across matches is relatively lower for both groups, as was revealed in the rest periods analysis, the biofeedback group had consistently lower EMG than the placebo group. When highly stressful situations occurred (e.g., stress data in matches 1 and 5), interactions became evidenced. Referring to Figure 1, a clear interaction in match 5 can be observed whereby biofeedback subjects showed lower EMG before the first game. They lost this first game, however, and it was made clear to them before playing game 2 that they had to win the two following games in order to win the tournament. It would thus be reasonable to assume that competitive stress was higher before game 2 than game 1.

In that situation it appears that groups did not distinguish themselves when the game to be played was most stressful (see game 2, match 5, in Figure 1). However, in a relatively less stressful situation (see game 1, match 5), the two groups had notably opposite EMG responses. One may speculate that these results suggest a certain threshold of precompetitive stress for which the biofeedback group could manage their EMG; beyond that threshold no difference occurred. This would warrant further investigation in order to verify if this threshold could also vary as a function of biofeedback (or stress management) training.

A second important finding of this study is that biofeedback subjects can transfer their specific EMG control to certain precompetitive stress situations—without the help of the biofeedback instrument (see Figure 1). Other studies verifying the transfer of EMG biofeedback to stressful situations have also reported similar results (e.g., Burish et al., 1981; Gatchel, Korman, Weiss, Smith, & Clarke, 1978). The present results are quite significant as they support the notion that youngsters can learn to achieve lower levels of specific target muscle tension with the biofeedback instrument, then transfer such learning to competitive stressful situations just moments before performing.

Furthermore, this study extends previous results to a different population and to a different stressful environment, that is, to young, high trait-anxious boys participating in a controlled sport competitive situation. Previous controlled studies were conducted with college or adult populations and the stress induction was typically an anticipation to an electrical shock (e.g., Burish et al., 1981; Davis, 1980). The present study attempted to increase the external validity by recreating as much as possible a real sport competitive environment. Indeed, the competitive stress manipulation appeared to be quite credible. The multivariate stress/rest main effect demonstrating marked activation, and lowering arousal from stress to rest periods across matches, supports the manipulations used.

Perhaps the most interesting indication of the stress induction was revealed by the univariate stress periods main effect of state anxiety whereby anxiety levels varied significantly within matches 1 to 4. The analyses revealed that the majority of these variations appear to be a function of previous game or match objective success-failure. The inclusion of a no-stress control group in a similar design, however, would permit a more definite statement on the effect of this competitive stress induction. Nevertheless, these results support previous studies on the effect of success-failure on state anxiety (see Martens, 1977) in the sports domain. In addition, these results emphasize the importance of controlling for success-failure experiences in studies evaluating the effects of sport competitive stress-coping strategies.

Do the present results offer support for the discriminative/skill learning model as opposed to the trophotropic rebiasing model? The answer appears to be yes, if we base our observations on group mean differences (i.e., MANOVA and ANCOVA results). However, if we attend to individual differences through within-group zero order correlations, the answer appears more complicated. Biofeedback subjects' EMG tended to become more positively correlated with heart rate and state anxiety as well as more negatively correlated with performance (i.e., lower pregame EMG, higher time on balance) from the first match to the last match. Though these results are descriptive and statistically nonsignificant, they nevertheless appear to be in line with predictions from the trophotropic rebiasing model in stating that covariations between the EMG target modality and other stress-related modalities should increase with training. However, the correlations between biofeedback subjects' EMG and respiratory rate did not share the same pattern. The placebo group's covariation pattern across time frequently showed either lower coefficients or greater coefficients in the opposite direction across matches. These results are quite intriguing, and any attempt to explain them at present would be premature and possibly misleading. In any event, the pattern of correlations observed in this study would surely call for future investigations.

In terms of practical implications, the present study suggests that young sport participants can readily learn to relax a specific muscle group such as the frontalis through biofeedback training. Results also appear to suggest that young athletes can use the learned skill without the equipment to better control specific muscle tension before an important competition. However, this may not necessarily help them feel less anxious, have a lower arousal condition, or make them perform better. Nevertheless, learning to relax a specific muscle group may become important for an athlete suffering from localized muscle tension and accompanying pain (e.g., as is the case with an injury). In such an instance, biofeedback on that muscle may be an efficient means of increasing awareness and control of its tension level.

As a final point, the following question may be addressed: Is biofeedback more efficient than other, less expensive relaxation techniques? This can be answered in future controlled studies in the sports domain. Results of studies in experimental and clinical psychology are still inconclusive with respect to the relative efficacy of various strategies for reducing specific target muscle tension (e.g., Qualls & Sheehan, 1981). With respect to control over anxiety, general arousal, and enhanced performance, we tend to agree with several others (e.g., Burish et al., 1981; Roberts, 1985; Silver & Blanchard, 1978) that the state of affairs remains inconclusive. Future studies should attempt to determine what kind of stress-coping strategy may be more efficient for what type of person under what kind of situation.

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Acknowledgments

We would like to thank Suzie Lamoureux and Angèle Southière for their invaluable help as research assistants, Jean-Louis Boucher and Terry Orlick for their support and valuable suggestions, Don Dickie, Pierre Lepage, Pierre McNichol, Joy Slack, and CHRO radio station for their help in the elaboration of the simulated competitive environment, and finally Claude Mongeau for valuable suggestions and assistance with statistical analyses.

Manuscript submitted: November 19, 1985
Revision received: July 3, 1986