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Defence and Civil INSTITUTE OF ENVIRONMENTAL MEDICINE

INSTITUT DE MEDECINE ENVIRONNEMENTALE pour la défense

1133 Sheppard Avenue West, PO Box 2000, North York, Ontario, Canada M3M 3B9
Tel. (416) 635-2000 Fax. (416) 635-2104

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THE INFLUENCE OF BIOFEEDBACK AND AUTOGENIC TRAINING ON MOTION SICKNESS TOLERANCE

E.E. Jozsvai
R.A. Pigeau

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Ave West, P.O. Box 2000
North York, Ontario
Canada M3M 3B9

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The influence of biofeedback and autogenic training on motion sickness tolerance.

Emoke E. Jozsvai and Ross A. Pigeau

Executive Summery

The objectives of the experiment were: (a) to evaluate whether or not increased control over autonomic nervous system (ANS) responses is gained through the specific effect of biofeedback, (b) to assess the effects of learned control of ANS responses upon motion tolerance, and (c) to ascertain the relationship between ANS self-control and coping with motion stress.

Three groups of six subjects were exposed for six weeks to weekly sessions of Coriolis stimulation to induce motion sickness. Between the first and second Coriolis sessions, subjects in the experimental groups received five episodes of autogenic feedback (biofeedback) training with either true (group TFB) or false (group FFB) feedback on their heart rate (HR) and skin temperature (ST). The control group (CTL) received no treatment.

The results showed that subjects can learn to control their ST and HR through instruction for autogenic practice alone. Continent and noncontingent biofeedback made no difference in this learning. The results also showed that ST and HR are valid correlates of motion sickness, because when they were motion sick, HR increased whereas ST decreased in all three groups of subjects.

Following autogenic-feedback training the TFB group tolerated more rotations and reported less symptoms of motion sickness than the FFB and CTL groups. There was no significant improvement in the post-training rotation scores of the latter groups. However, the superior motion tolerance of the TFB group resulted solely from the performance of three subjects. There were large increases in the post-treatment rotation scores of these subjects, whereas the rest of TFB group performed at the same level across motion tests as the CTL subjects. From the FFB group only one subject improved in post-treatment rotation tolerance.

Learned control of ST and HR was not related to subject's ability to withstand Coriolis stimulation following treatment. A lack of significant correlation between these variables suggested that subjects were not able to apply their skills of ANS self-regulation in the motion environment, and/or such skills had little value in enhancing their ability to withstand rotations.
However, subjects with high baseline motion tolerance tended to improve more after autogenic-feedback training than subjects with low baseline rotation tolerance.

The findings of the experiment indicate that ANS self-regulation is not an effective technique to enhance the ability to cope with motion sickness.

Key words: Biofeedback, autogenic training, motion tolerance.

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ABSTRACT

Three groups of six subjects were exposed for six weeks to weekly sessions of Coriolis stimulation to induce motion sickness. Between the first and second Coriolis sessions, subjects in the experimental groups received five episodes of autogenic feedback (biofeedback) training with either true (group TFB) or false (group FFB) feedback on their heart rate (HR) and skin temperature (ST). The control group (CTL) received no treatment. Subjects learned to control their HR and ST independent of whether they received true or false feedback. Learned control of ST and HR was not related to subject's ability to withstand Coriolis stimulation following treatment.

Motion sickness is an occupational stress endured on highways, at sea, in the air and in space. The incidence of motion sickness depends on the character and duration of the motion stimulus and on the susceptibility of the individuals exposed. Dobie (8) has reported that 39% of pilot trainees suffer from motion sickness at one time or another while Wood and his coworkers (24) have found that 50% of space crew suffer from motion sickness. Motion sickness at sea has often been considered to be the most devastating. Birren (2) found that 62.4% (319 of 511 naval personnel with an average of two years sea experience) reported some susceptibility to seasickness. More recently, Pethybridge (18) reported that of the 1746 Royal Navy personnel who completed questionnaires, 70% reported episodes of seasickness and 20% of sailors reported that they were frequent seasickness suffers. Although Pethybridge found that the malady was incapacitating in only 4% of the individuals among those who suffered from seasickness "very often", 96% of these sailors reported heightened job difficulty and 63% reported great difficulty with job performance. Among those who suffered from seasickness only "sometimes", 2% were incapacitated but 78% reported difficulty in performing their job. Thus, motion sickness may not always lead to incapacitation but it can result in substantial job performance deficits.

The most frequent manifestations of motion sickness are nausea, vomiting, drowsiness, fatigue, pallor, cold sweating and/or loss of appetite (1). Prior to or during episodes of motion sickness, individuals may also show idiosyncratic patterns of Autonomic Nervous System (ANS) responses, such as changes in heart rate (HR), respiration rate (RR) and/or basal skin resistance (SR) (6).

Although motion sickness seems to be associated with ANS changes, the role and importance of ANS responses in the syndrome has been a matter of controversy (for review see ref. 6). Money (16) has argued that "to the extent that motion sickness is nausea and vomiting, it is not an autonomic phenomenon and it cannot be considered a development of the autonomic effects of vestibular stimulation" (p 4.). On the other hand Crampton (7) reported specific autonomic consequences for individuals susceptible to motion sickness. In contrast to individuals who did not vomit as a result of motion stimulation, Crampton found that individuals who

vomited in response to an oscillation motion test showed (a) a greater increase in pulse rate, (b) greater vasoconstriction, (c) more abrupt decrement in gastric tone, (d) more sweating, and (e) more facial pallor. However, since there were marked individual differences in these measures, Crampton (7) concluded that the value of using ANS measures to accurately characterize motion sickness is equivocal. In a subsequent study, Graybiel and Lackner (11) assessed the relationship between symptoms of motion sickness, body temperature, HR and blood pressure. No consistent relationship was found between symptoms of motion sickness and the above ANS indices. In view of this, the authors concluded that "such measures... appear to have little value in assessing or diagnosing (the) severity of motion sickness. This lack of correlation means that use of physiological training procedures to control these variables is likely to be of little value in preventing symptoms of motion sickness" (p.214).

In contrast, Cowings and her colleagues (6) reported that there are symptomatic differences in autonomically mediated responses between subjects with low, moderate and high motion sickness susceptibility. These authors found that HR, RR, and basal skin resistance dramatically changed during motion stimulation and that changes in these ANS measures were larger in the high than in the low or moderately motion sickness susceptible groups.

Cowings (3) claims that symptoms of motion sickness are controllable through self-regulation of ANS responses, and that the best method to teach such control is autogenic-feedback (biofeedback) training. In support of this conclusion Cowings and her coworkers performed an experiment (5) in which three groups of eight subjects were exposed to six rotating chair tests separated by 5 day intervals. Between rotation tests 3 and 4 Treatment Group I received 2.5 h of autogenic-feedback training. For Treatment Group II autogenic-feedback training (2.5 h) took place between rotation tests 5 and 6. Control Group III received no training. Groups I and II were taught the standard exercises of autogenic therapy. Verbal, visual and/or auditory feedback was provided on HR, RR and blood volume pulse. Training took place in the motion environment where subjects were either rotated at low speed (no headmovement) or performed headmovements (no rotation) at 2-sec intervals. During

post-treatment motion tests Groups I and II were able to tolerate motion stimulation significantly longer and exhibited fewer signs of motion sickness than prior to training. For Control Group III there was no significant improvement in motion tolerance or in scores of motion sickness across motion tests. In the sixth rotation test members of this group tolerated significantly fewer rotations than subjects in training Groups I and II.

More recently, however, a study by Dobie, May, Fischer, Elder and Kubitz (9) found that biofeedback training is ineffective for reducing symptoms of motion sickness or increasing tolerance to motion stimulation. Dobie and his coworkers (9) compared the efficacy of two training methods to increase tolerance of visually-induced motion sickness. Group BT was exposed to ten sessions of confidence building and desensitization (cognitive-behavioural therapy); Group FB received ten sessions of electromyogram (EMG) and skin temperature (ST) feedback training; group BTFB was exposed first to biofeedback (ST and EMG) (ten sessions) and subsequently to confidence building and desensitization (ten sessions) training. Subjects in Group C received no treatment. Following training both BT and BTFB groups, but not Groups FB and C, were able to tolerate motion stimulation significantly longer with less symptoms of motion sickness than prior to training. However, when the effects of biofeedback versus cognitive-behavioural training were evaluated only the cognitive-behavioural training group showed increased motion tolerance and reduced symptoms of motion sickness.

The incongruence between Dobie's findings and the results from Cowing's study may be attributed to interexperimental methodological and procedural differences. In Dobie's study the subjects did not achieve significant skin temperature control and, although they learned EMG control, this learning was not utilized by them in the motion environment during post-testing. The extent to which Cowings' subjects learned to control their ANS responses is not known however, because these authors did not report the results of their autogenic-feedback training. Thus, in lack of such data the actual relationship between ANS self-regulation and motion tolerance and/or symptoms of motion sickness remains unknown.

The studies of Dobie et al., and Cowings at al., also differed in terms of the feedback modalities employed. Dobie and his coworkers provided feedback only on ST and EMG activity. In the experiment of Cowings et al., subjects received feedback on HR, RR, blood volume pulse and were instructed to concentrate on those ANS responses that were most prominently associated with their individual symptoms of motion sickness. However, the autogenic-feedback groups were trained by Cowings at al., under conditions of low rotation while the control subjects received no treatment. Thus, post-treatment increases in motion tolerance and reduction in symptoms of motion sickness in the treatment groups may have been due to their additional 2.5 h exposure to adaptive motion stimulation.

It may also be possible that the treatment gains reported by Cowing et al. resulted from a placebo effect and had little to do with the specific effect of biofeedback. According to Furedy (10), "the specific effect of biofeedback is the increase of control over involuntary functions that is gained through the feedback information delivered through the instrumentation to the patient. Other factors such as feedforward information (instruction), the therapist patient rapport may be very powerful, but are part of the placebo and should be eliminated in any scientific study of biofeedback as phenomenon,... and in any adequate evaluation of biofeedback as the therapeutic treatment mode" (p.160). Thus, to properly evaluate the specific, beneficial effects of biofeedback vis a vis motion tolerance and symptoms of motion sickness, a control condition that is identical in every respect to the biofeedback condition, except for the biofeedback itself, should be employed. "Since the feedback signal is contingent on the target function to be modified, the required control condition is often referred to as a noncontingent or "false feedback" control condition" (10).

The objectives of the present experiment are as follows: (a) to evaluate whether or not increased control over ANS responses is gained through the specific effect of biofeedback, (b) to assess the effects of learned control of ANS responses upon motion tolerance and symptoms of motion sickness, and (d) to ascertain the relationship between ANS self-control and coping with motion stress.

The preceding literature review suggests the following specific hypotheses: (1) if biofeedback facilitates learning of ANS self-

regulation then autogenic training with true feedback should lead to superior control over ANS responses than autogenic training with false feedback; (2) if autogenic-feedback training is an effective method to enhance coping with motion stress then autogenic training with true feedback should lead to superior motion tolerance and less symptoms of motion sickness than false feedback or not training; (3) If there is a relationship between ANS self-regulation and coping with motion stress a significant correlation should be found between amounts of control over ANS responses and measures of motion tolerance and/or symptoms of motion sickness.

Method

Subjects

Eighteen volunteers (between 18 and 45 years of age) were recruited from the Defence and Civil Institute of Environmental Medicine (DCIEM) and from the student population of York University. Participation was contingent on the subject's being susceptible to motion sickness (measured by a questionnaire on personal experience with motion sickness) and in good physical health (assessed by medical screening at DCIEM).

Subjects received a brief summary of the experimental protocol and were informed in writing about the possibility of discomfort (e.g., nausea, dizziness, tiredness) resulting from exposure to motion stimulation. Written consent to participate in the study was obtained from each subject and they were reminded of their rights to withdraw from participation at any time. Subjects were requested not to consume alcohol 24 h prior to experimental sessions. Subjects received monetary compensation for their efforts at the end of the study.

Tests and Apparatus

Motion platform

Motion sickness was induced by using the rotating Coriolis chair. The Coriolis chair was equipped with an automatized headrest that moved forward and backward at 2 sec intervals. For a more complete description of the Coriolis chair see Sunahara et al. (23).

Approximately 1 m in front of the Coriolis chair, at eye level, a television monitor was secured to the motion platform. It provided the visual stimuli used in the feedback portion of the experiment. Auditory feedback stimulation and verbal communication between the experimenter and the subjects took place with headphones and microphones.

Assessment of ANS responses

Physiological responses were collected and recorded by a J&J Instruments Biomonitoring System. Heart rate was derived from a photoplythesmograph (placed on the index finger of the right hand). Skin temperature (ST) was measured through a thermistor (placed on the small finger of the right hand). Physiological signals were locally amplified and filtered using equipment secured to the motion platform. The signals were then delivered to the J&J Biomonitoring System through sliprings placed under the motion platform.

Biological feedback of ST and HR was provided both through the earphones in the form of an auditory signal and the television monitor using a digital display. When the subjects' mean ST (averaged over 10-sec) decreased or increased 0.5 standard deviation from the average baseline skin temperature value, a 2 sec auditory signal was activated. Concomitant with the tone, the visual display showed either "Attention, Cooling" (when ST decreased) or " Good, Warming" (when ST increased).

During HR feedback sessions an auditory signal was activated whenever the subjects' mean HR (averaged over 5-sec) increased 0.5 standard deviation from their average baseline HR value. The tone remained active until HR decreased to the mean baseline value or below. Mean HR was also digitally displayed on the television monitor throughout the session.

False feedback (described in the next section) was provided with the aid of a VCR from a videotape.

Procedure

Motion tests

To familiarize the subjects to the motion platform and to the experimental protocol, they were seated in the Coriolis chair without being rotated in an initial 15-min long session. Subsequently, the subjects were exposed to six rotation tests separated by one week, to minimize habituation to motion stimulation. During these tests each subject was rotated around his/her own vertical axis. The initial speed of rotation was 6 rpm and it was increased by 2 rpm every 3 min to a maximum velocity of 30 rpm. During each 3 min interval, while rotating at a constant speed, the subjects underwent 90 degree head movements (at 2-sec intervals) in two directions (forward and backward) by following the motion of the automatized headmovement device. The proper execution of head-movements was carefully monitored by the experimenter. During rotation, as a result of the Coriolis effect induced from the head movements, symptoms of motion sickness are often manifested. Each 3-min period of rotation and headmovement was followed by a 30 sec interval (without headmovement) during which the Coriolis Susceptibility Index (CSSI) (15) was administered. The CSSI is a diagnostic scale designed to assess subjective symptoms of motion sickness (e.g., reports of sweating, nausea, facial pallor) and yields a subjective numerical score for each subject. Coriolis stimulation was terminated at 30 rpm or upon the verbal request of the subject, whichever came first. The subjects were instructed that rotation would be terminated if they reported feeling slight but unequivocal nausea.

During all periods of rotation, HR and ST were recorded in 5-sec intervals for each subjects. These ANS indices were also collected during 6-min resting and recovery baselines given immediately before and after each experimental session.

Autogenic-feedback training

The first rotation session was used as a baseline for each subject. Indices of ST, HR, number of rotations tolerated and scores of motion sickness collected in this session were used to evaluate the

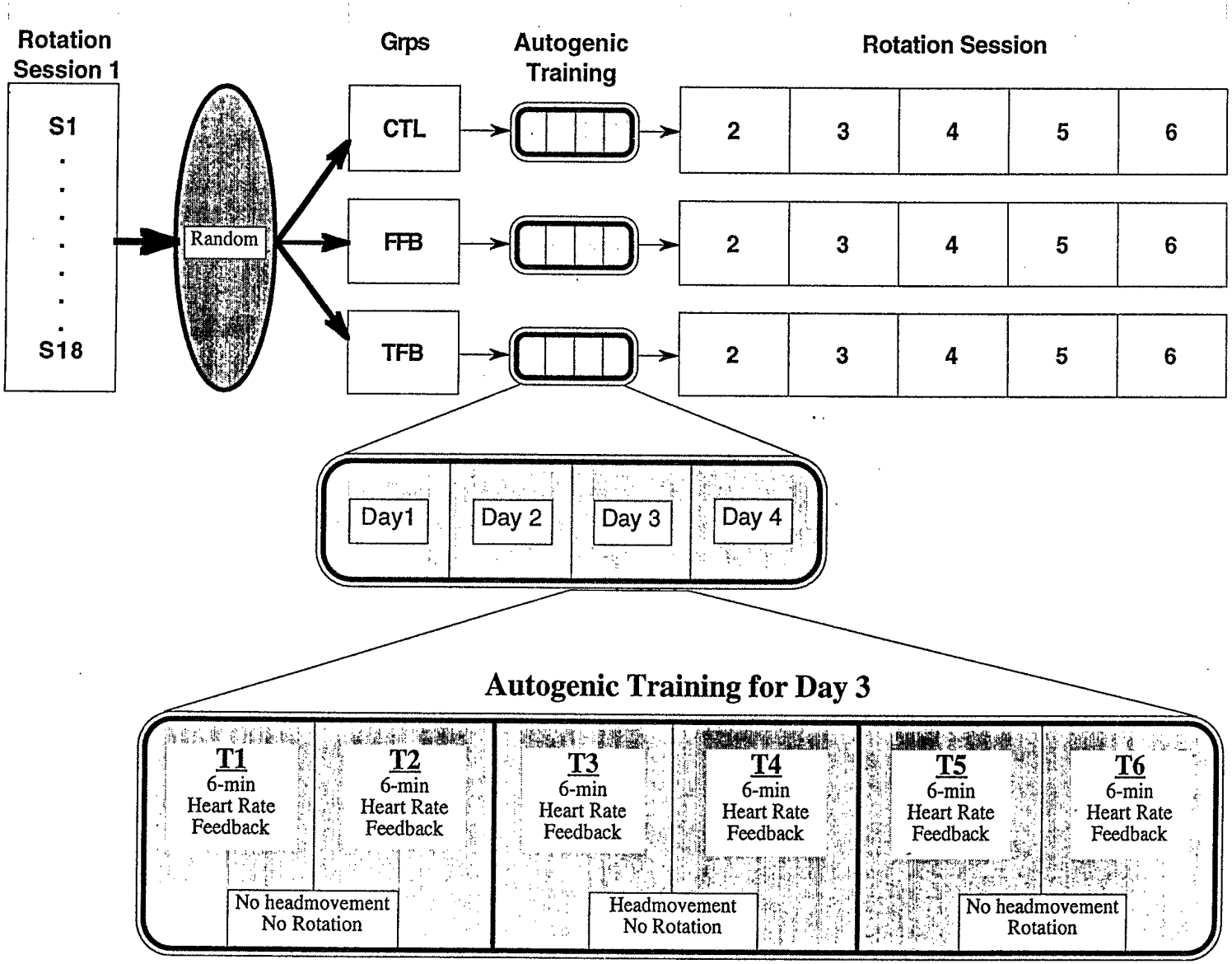
effectiveness of autogenic training. Following session 1, subjects were randomly assigned into either control (CTL), true-feedback (TFB) or false-feedback (FFB) autogenic training groups. Between rotation sessions 1 and 2, groups TFB and FFB received four consecutive 36-min long daily sessions of autogenic-feedback training (see Figure 1).

Each autogenic-feedback training session began with a baseline period during which subjects were instructed to sit quietly in the (non-rotating) Coriolis chair. The remaining of the session consisted of six trials (T), 6-min long each, of autogenic practice under the following conditions: (a) while seated in the Coriolis chair (T1, T2) (no headmovement or rotation), (b) while performing headmovements in 2-sec intervals (T3,T5) (no rotation) (c) while being rotated at 6 rpm (T4,T6) (no headmovement). Throughout all sessions HR and ST was recorded in 5-sec epochs.

As outlined by Neidhardt et al. (17) and Schultz and Luthe (22), TFB and FFB groups were instructed to silently repeat simple self-directing phrases that refer to heaviness in the limbs (e.g. "my arms and legs are heavy"); sensations of warmth (e.g. "my arms and legs are warm"); regular heart beat (e.g. "my heartbeat is regular"); and easy, natural breathing (e.g. "my body breathes me"). In practising the Standard Autogenic Formulae for heaviness (relaxation) and warmth (increased circulation) (training sessions 1-4), cardiac regulation and respiration (training sessions 3 and 4), subjects in the TFB group were aided by auditory and visual feedback on their ST (training sessions 1 and 2) or HR (training sessions 3 and 4). For the FFB group feedback on ST and HR was given non-contingently (false feedback) from a videotape that contained the ST (sessions 1 and 2) or HR (sessions 3 and 4) feedback session of the best performing subject in the TFB group.

The CTL group was exposed to the same conditions (i.e. baseline, and trials with rotation or headmovement) as the TFB and FFB groups without being instructed to perform any specific exercises or being provided with feedback on their physiological activity.

Figure 1: Experimental Design



Results

ST and HR during autogenic-feedback training

ST and HR data from baseline and autogenic practice trials were collapsed to 6-min averages for each subject, trial and session. To evaluate the effect of autogenic-feedback training, difference scores were calculated for ST and HR by subtracting the mean of T1 and T2 from the pre-session resting baseline mean. T1 and T2 were chosen because during these trials subjects were practising the autogenic exercises without being influenced by rotation or headmovement. The ST and HR difference scores from the last two sessions of training were subjected to a 3x2x2 (group x session x trial) ANOVA with sessions and trial treated as repeated measures.

The ST difference scores for training session 3 and 4 are plotted in Figure 2. Figure 2 shows that TFB and FFB groups had higher skin temperatures than the CTL group. Although, the ANOVA did not yield significant main effect for groups ($F(2,15)=1.449$), subjects in the TFB and FFB groups learned to increase their skin temperature both within and across sessions. This was indicated by a significant main effect for trials ($F(1,15)=10.47$ $p<0.005$), and significant group x session ($F(2,15)=4.5$ $p<0.02$) and group x trial ($F(2,15)=6.4$ $p<0.009$) interactions. ANOVAs on simple main effects showed no significant difference between TFB and FFB groups. Thus, irrespective of feedback, by practising the autogenic exercises subjects in these groups learned to increase their ST.

The analysis of HR difference scores from the HR feedback training sessions yielded a significant main effect for group ($F(2,15)=8.1$ $p<0.00$). There was no significant main effect for sessions ($F(1,15)=1.4$) nor were there any significant interactions involving trials, group and session (all F's <1.4). The plots in Figure 3 (see page 11) show that groups TFB and FFB were able decrease their HR during both training trials whereas subjects in the CTL group showed no change in HR. However, groups TFB and FFB did not differ statistically in terms of HR control. This result is similar to those showed for ST and indicates that autogenic practice alone (i.e. without feedback) is effective to reduce HR.

After establishing that giving autogenic instructions alone seems to be sufficient for controlling ST and HR, we evaluated the effect of this learning on HR and ST during motion stimulation and on subject's ability to withstand rotation and symptoms of motion sickness. Recall that for the TFB and FFB groups subjects were instructed to perform the autogenic exercises during the rotation sessions.

ST and HR during rotation tests

ST and HR data from rotation tests was collapsed to 3-min averages for each increment of rotation tolerated and to 6-min means for pre-rotation resting baseline periods. For each subject, ST and HR difference scores for increments of rotation were calculated by subtracting from the mean of resting baseline the average values of each completed rotation step. The difference scores for the first and last completed 3-min increment of rotation were analyzed by 3x6x2 (group x rotation x trial) ANOVA.

ST and HR difference scores, collapsed across all rotation sessions for the first and last 3-min rotations tolerated by the three groups are plotted in Figure 4 and 5, respectively. Figure 4 shows that subjects reacted similarly to motion stimulation. That is, relative to the first 3-min rotation, ST during the last 3-min rotation decreased for all three groups of subjects. This was indicated by a significant main effect for rotation trials ($F(1,14)=11.3$ $p< 0.005$). Although decreases in ST were larger in the CTL than in the TFB and FFB groups, the main effect for groups and the interaction involving groups and trials was not statistically significant.

Similar results were obtained from the analysis of HR data. Visual inspection of Figure 5 reveals that HRs during the last 3-min increment of rotations tolerated were higher than during the first 3-min of rotations. The ANOVA showed no significant main effect for groups ($F(2,14)=0.4$), but the main effect for trials approached statistical significance ($F(1,14)=4.1$). These results suggest that autogenic-feedback training was not effective to prevent ST and HR changes that occur when subjects experience motion sickness.

Figure 2. Mean skin temperature difference scores for two sessions of treatment condition

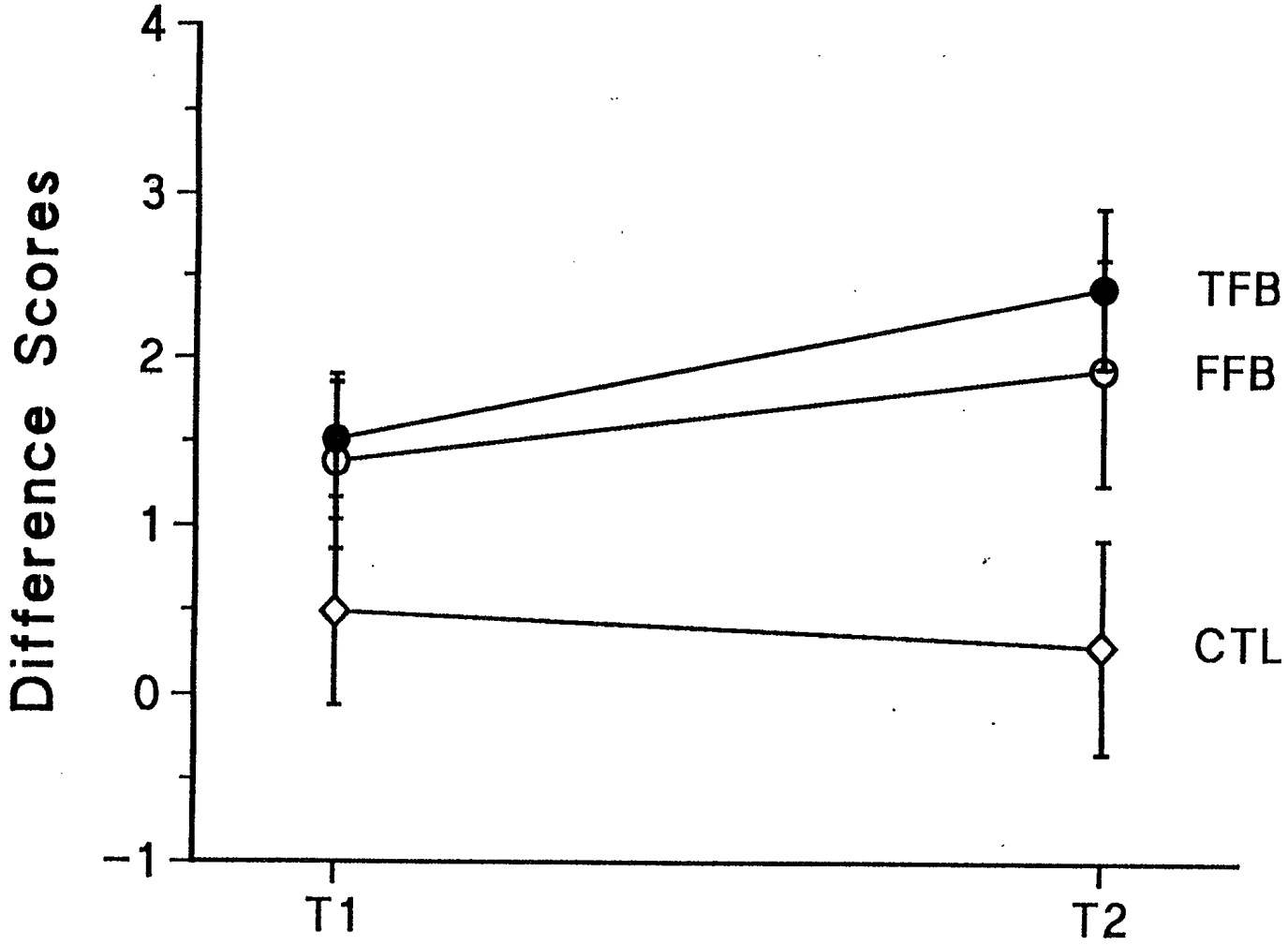
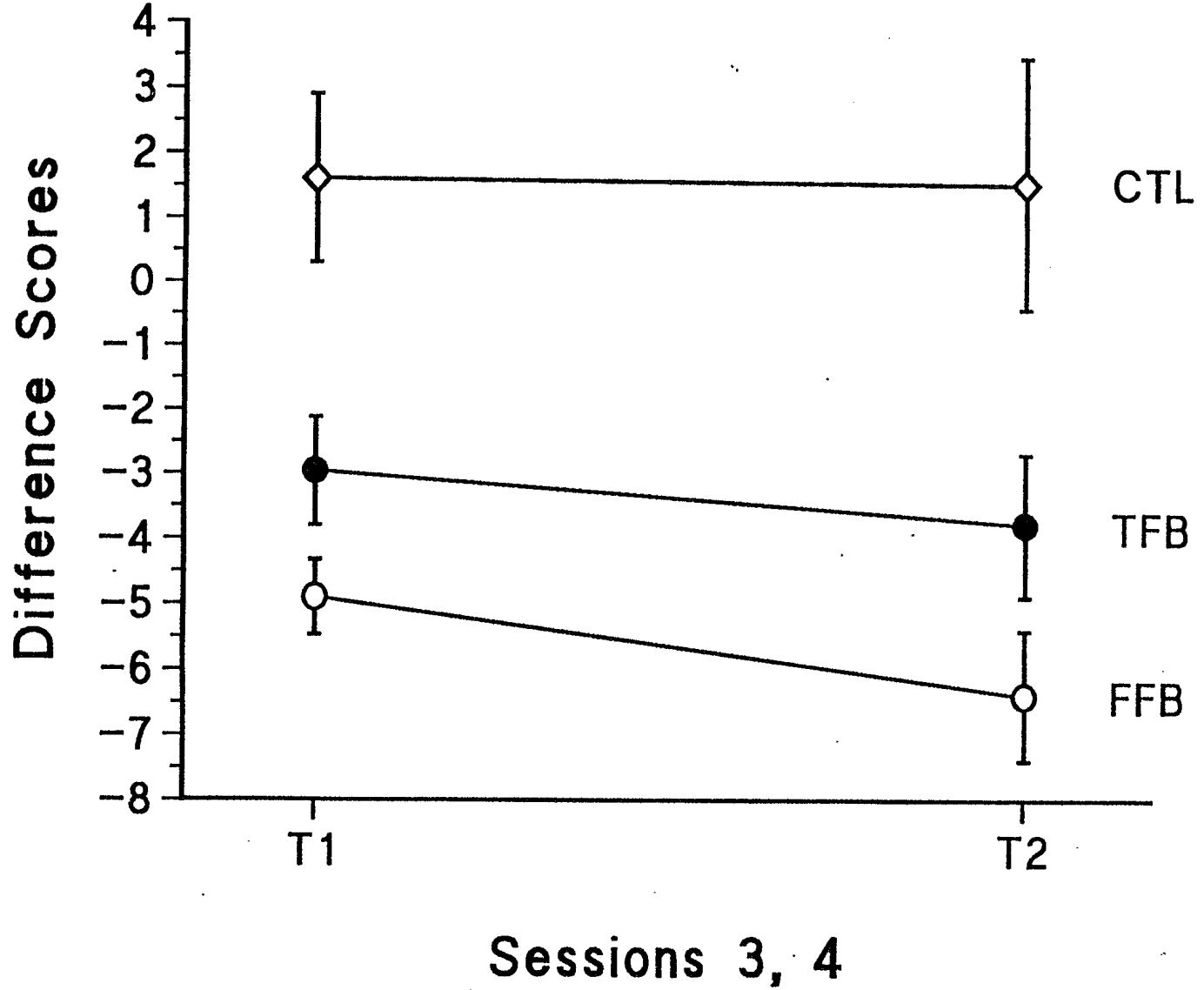


Figure 3. Mean heart rate difference scores for two sessions of treatment condition



Motion Tolerance

To control for individual differences in baseline ability to tolerate motion, difference scores were calculated for each subject by subtracting from the total number of rotations achieved during rotation test 1 from the number of rotations achieved in each of subsequent rotation tests. The obtained difference scores were subjected to a repeated measures ANOVA.

The ANOVA yielded significant main effects for groups ($F(2,15)=3.4$ $p<0.05$), rotation tests ($F(5,75)=7.9$ $p<0.000$), and a significant group x rotation test ($F(10,75)=2.3$ $p<0.01$) interaction. These results are illustrated in Figure 6. Figure 6 shows that in rotation test 2 through 6 the TFB group was able to tolerate more rotations than subjects in the FFB and CTL groups. For the TFB group the most dramatic increases in number of rotations tolerated occurred in rotation test 2, i.e., following the completion of four sessions of autogenic-feedback training. There were only small increases from test 1 to 2 in the number of rotations achieved by groups FFB and CTL. Although group CTL showed a slight trend towards increased motion tolerance, group differences were maintained across rotation tests 2 to 6.

As reflected in Figure 6, there were considerable differences in standard errors across the three groups. An examination of within group individual differences revealed that three subjects in the TFB group, and one subject in the FFB group contributed to the large error variance. Following autogenic training, there were large increases in the number of rotations tolerated by these four subjects whereas other members of the TFB and FFB group showed slight or no improvement across rotation tests, thus resembling the CTL group. It may be that individual differences in rotation tolerance were related to between subject differences in ability to learn ST and/or HR control during sessions of autogenic-feedback training. To evaluate this possibility, a rank order correlation was calculated between mean rotation difference scores (averaged over rotation tests 2-6) and ST and HR difference scores averaged over the last two sessions of autogenic training. The obtained correlation coefficients (all r's <0 .3) did not reach statistical significance. Thus,

individual differences in learned control of ST and HR were unrelated to subject's post-training motion tolerance.

It is also possible that subjects with high and low baseline motion tolerance differently benefitted from autogenic training. To evaluate the this, the TFB and FFB subjects were ranked on their baseline (motion test 1) rotation scores and on their post-training (motion tests 2 to 6) mean rotation difference scores. A significant rank order correlation coefficient ($r=.58$ $p<0.01$) obtained between these variables indicates that subject's with high baseline motion tolerance were able to benefit more from autogenic training than subjects with low initial motion tolerance.

Motion sickness symptoms

Scores of motion sickness were derived from CSSI diagnostic scale (15). Difference scores were calculated for each subject by subtracting the CSSI score for rotation test 1 from the CSSI score obtained in each of subsequent rotation tests. The motion sickness difference scores were analyzed by a mixed ANOVA.

The mean CSSI difference scores of the three groups are plotted for the six rotation test in Figure 7. Figure 7 shows that following autogenic-feedback training for the TFB group scores of motion sickness decreased across rotation tests. Although there was a decrease across sessions in the CSSI scores of FFB and CTL groups, both these groups reported more symptoms of motion sickness than subjects in the TFB group. The ANOVA showed a significant main effect for trials ($F(5,75)=2.5$ $p<0.03$). There was no significant effect for groups or interactions involving groups and trials ($F's< 0.5$). As with the previous results, the effect is attributable to same three subjects.

To investigate whether subjective estimates of motion sickness vary with objective ANS measures the Pearson's correlation was calculated. A significant correlation coefficient ($r=0.59$ $p<0.04$) obtained between mean CSSI difference scores (averaged over rotation tests 2 to 6) and mean HR difference scores (averaged over rotation tests 2 to 6) collected from the last 3-min period of rotation tolerated. CSSI difference scores did not correlate significantly with

Figure 4. Mean skin temperature difference scores for the first and last 3-minute rotations for all groups

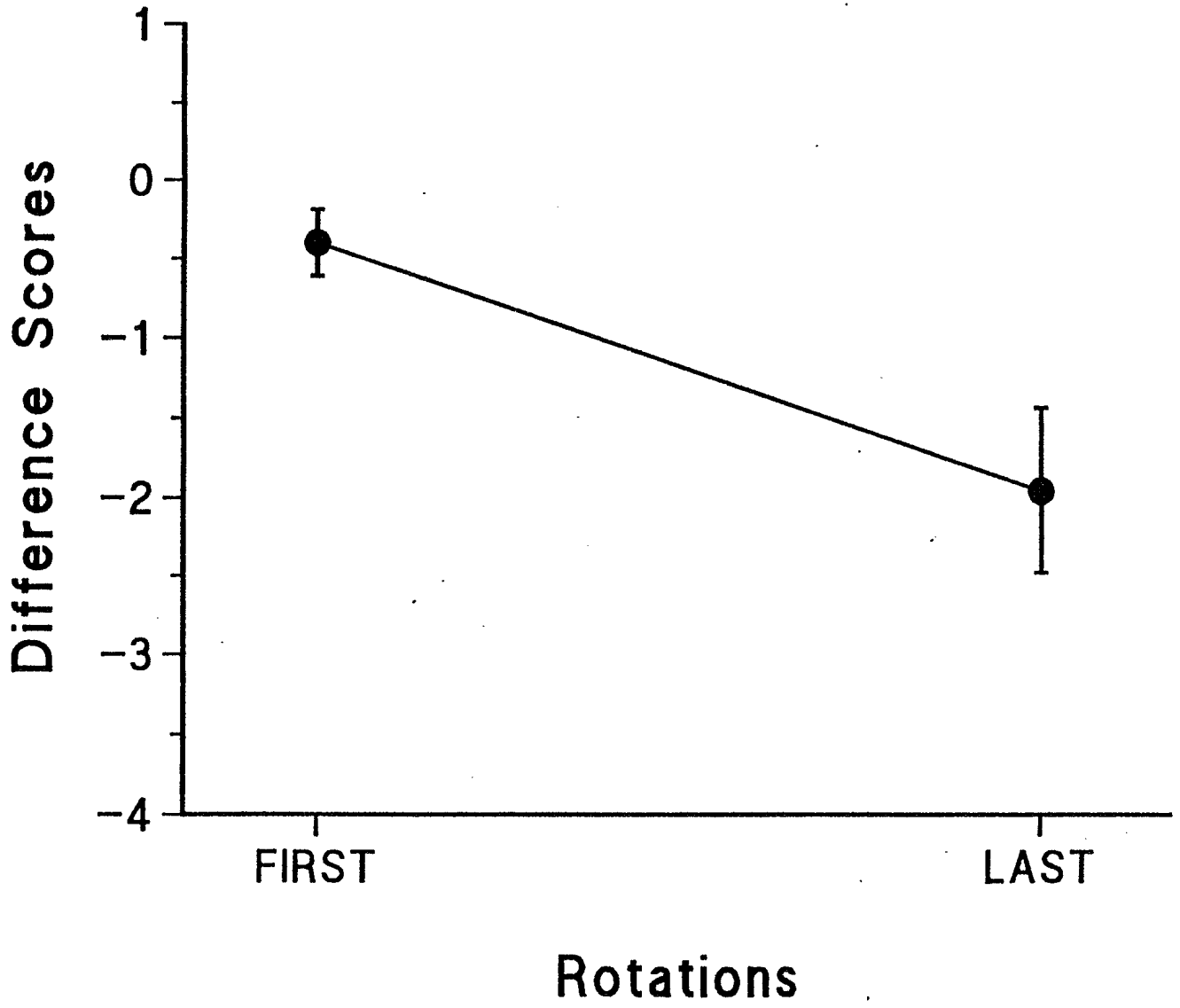
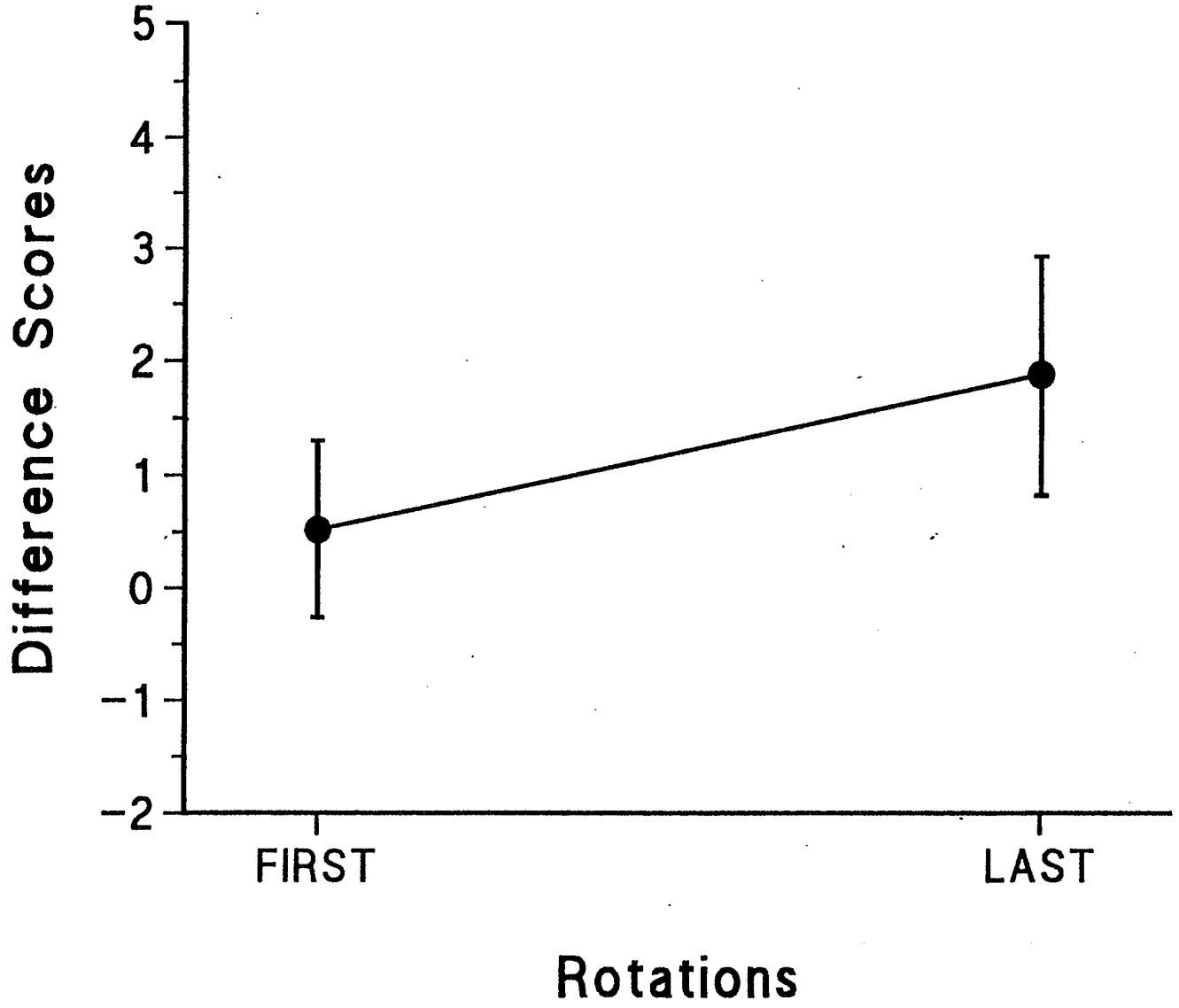


Figure 5. Mean heart rate difference scores for the first and last 3-minute rotations for all groups



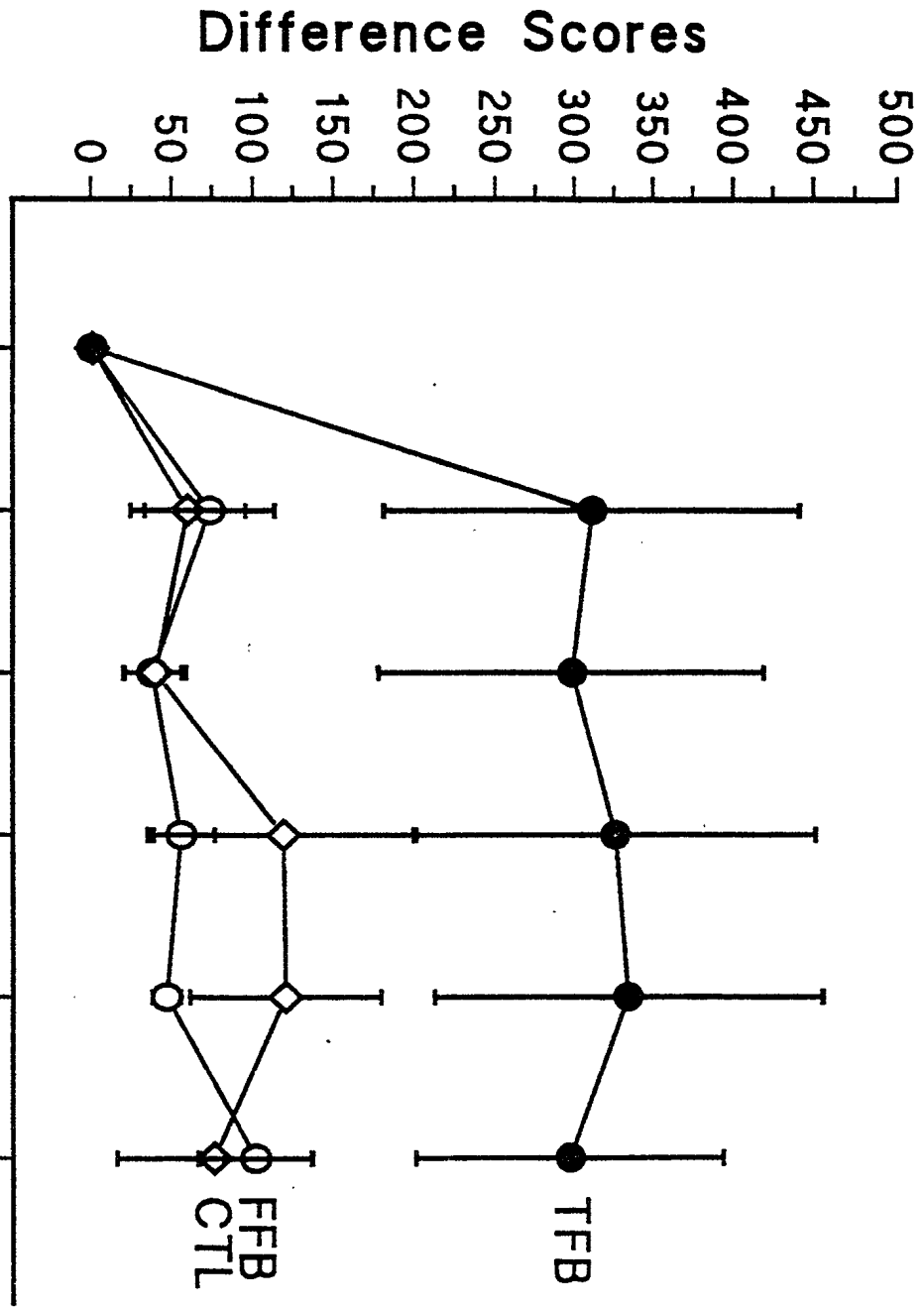
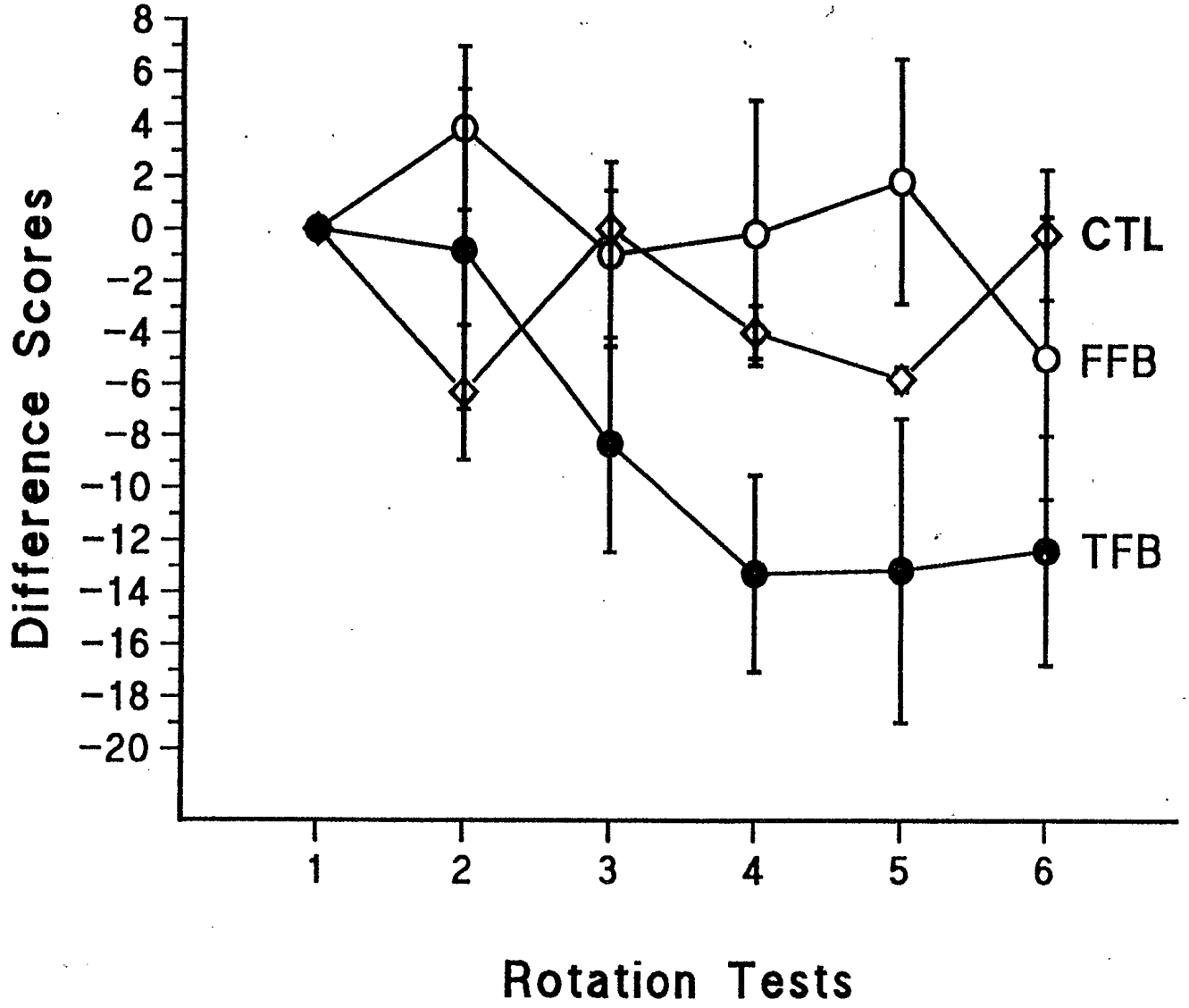


Figure 6. Mean difference scores of rotations

Figure 7. Mean difference scores of motion sickness measured by CSSI diagnostic scale



mean ST difference scores ($p>0.11$). Thus, HR appears to be a more sensitive to the motion sickness experience than ST.

Discussion

The objectives of the present experiment were (1) to evaluate whether or not increased control over ANS responses is acquired through the specific effect of biofeedback, (2) to assess the effects of autogenic training upon motion tolerance and motion sickness, and (3) given objective (2) what is the relationship between ANS self-control and ability to cope with motion stress?

The results showed that subjects in the TFB and FFB group learned to increase their ST and decrease their HR, whereas CTL group showed no meaningful changes in these indices of ANS activity. However, contingent, and non-contingent feedback had no effect on subjects' ability to learn the target responses, for the two treatment groups did not differ significantly in terms of ST and HR control. This suggests that control over these responses was established through instruction for autogenic practice, and the provision of exteroceptive feedback had no value in performance beyond the effects of instructions. These results are congruent with the findings of previous studies that compared the effects of contingent and non-contingent feedback procedures on HR control. Subjects can produce HR changes upon instruction, independent of whether they are given contingent- or non-contingent feedback (12, 13, 20, 21) or receive no feedback (14). That instructions are sufficient to produce HR changes may be attributed to the fact that most participants of biofeedback experiments are familiar with the HR response and possess behavioural skills that allow them to modify their HR in a desired direction (21). In the present study, subjects were instructed to control their ST and HR through silent repetition of autogenic phrases and by concentrating on sensations of heaviness and warmth and on calm, regular heart beat. Although the practice of autogenic exercises is to decrease ANS and cortical activity, the precise mechanism by which this general physiological quieting is achieved remains unknown (for review see ref.19).

Autogenic-feedback training in the present experiment was not effective in preventing ST and HR changes that occur when subjects experience motion sickness. This was surprising since in the course

of autogenic-feedback training subjects in both treatment groups learned to control their ST and HR to the same extent. In view of this, we expected that during post-treatment rotation tests the TFB and FFB subjects would show less motion induced ST and HR changes than the CTL subjects, and that both treatment groups would tolerate more rotations than the CTL group. This was not the case. The results showed that following autogenic-feedback training the TFB group tolerated more rotations and reported less symptoms of motion sickness than the FFB and CTL groups. There was no significant improvement in the post-training rotation scores of the latter groups. However, the superior motion tolerance of the TFB group can be attributed solely to the performance of three subjects. There were large increases in the post-treatment rotation scores of these subjects, whereas the rest of TFB group performed at the same level across motion tests as the CTL subjects. From the FFB group only one subject improved in post-treatment rotation tolerance.

To explain these results, we explored the relationship between baseline motion sickness susceptibility and post-treatment rotation scores. The observed positive correlation between these variables indicates that TFB and FFB subjects with high baseline motion tolerance tended to improve more after autogenic-feedback training than subjects with low baseline rotation tolerance. Similar findings were reported by Cowings and Toscano (4) from a study that evaluated the efficacy of autogenic-feedback training in groups of moderate and high motion sickness susceptible subjects. Following autogenic-feedback training, both groups improved gradually across motion tests, were able to tolerate more rotations and reported less symptoms of motion sickness than prior to training. However, across rotation tests, the high susceptible group showed less improvement, and slower rates of improvement than the moderate susceptible group. According to Cowings and Toscano (4), subjects that are highly susceptible to motion sickness tend to produce very large magnitude of ANS responses, and therefore may require more autogenic-feedback training (i.e., more practice) to achieve the same degree of motion-sickness tolerance as subjects with moderate or low susceptibility.

However, in the present experiment, practice effects and/or individual differences in learning of ANS self-regulation do not

account for between-subject variations in post-treatment motion tolerance. First, post-treatment rotation scores did not increase significantly across motion tests. Although subjects were instructed to practice autonomic self-control, their motion tolerance reached a plateau by the second motion test, i.e., right after the completion of autogenic-feedback training. Second, post-treatment rotation scores did not correlate significantly with scores of ST and HR control from autogenic-feedback training sessions. The lack of a meaningful relationship between these variables suggest that subjects were not able to apply their skills of ANS self-regulation in the motion environment, and/or such skills had little value in enhancing their ability to withstand rotations. Indeed, in the last 3-min rotation tolerated during motion tests, HRs increased whereas STs decreased in similar magnitudes for all three groups of subjects.

Thus, taken together, the findings of the present experiment do not support Cowings' claim (3) that ANS self-regulation is an effective technique to enhance the ability to cope with motion sickness. We found that over repeated exposure to rotations, subjective symptoms of motion sickness tend to decrease irrespective of training in ANS self-regulation and independent of improvements in rotation tolerance.

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Footnotes

1. Dr. E. E. Jozsvai is currently a consultant with EM Behavioral Research, 30 Holly Street, Suite 1403, Toronto, Ontario, M4S 3C2. Canada. This study was supported by NSERC post-doctoral fellowship to the first author.

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Three groups of six subjects were exposed for six weeks to weekly sessions of Coriolis stimulation to induce motion sickness. Between the first and second Coriolis sessions, subjects in the experimental groups received five episodes of autogenic feedback (biofeedback) training with either true (group TFB) or false (group FFB) feedback on their heart rate (HR) and skin temperature (ST). The control group (CTL) received no treatment. Subjects learned to control their HR and ST independent of whether they received true or false feedback. Learned control of ST and HR was not related to subject's ability to withstand Coriolis stimulation following treatment.

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