Relaxed and Alert: Patterns of T-wave amplitude and heart rate in a REST environment.

Gary Daniel Steel

B.A.(Honours), The University of Victoria, 1986

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in

THE FACULTY OF GRADUATE STUDIES

(Department of Psychology)

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

October 1988

©Gary Daniel Steel, 1988

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Psychology

The University of British Columbia
Vancouver, Canada

Date October 15, 1988

Abstract

Thirty-six subjects participated in a restricted environmental stimulation technique (REST) study investigating the psychophysiological effects of flotation. Subjects floated for one hour under differing expectations regarding duration of a float session and the physical properties of the environment that was to follow. EMG and two measures of cardiac activity (T-wave amplitude and heart rate) were recorded for the entire session; however, EMG was dropped as a variable due to an excessive noise-to-signal ratio. It was found that neither durational expectations nor beliefs about a dissimilar environment had any significant effects on the patterns of response of the two remaining variables. Subjects did show a significant within-subjects trend when considered as a whole group. Further research in the area of cardiovascular and muscle activity patterns in the flotation tank is suggested.

Table of Contents

Introduction	1
The Third-quarter Phenomenon	2
Parameters of the Third-quarter Phenomenon	3
On the Measurement of Arousal	6
Method	10
Design	10
Subjects	10
Procedure	12
Electrode Attachment	14
Equipment, Data Acquisition, and Scoring	15
Results	19
Data Reduction	19
Multivariate Analysis	21
Discussion	23
References	27
Appendices	30
A: Computer programs	31
B: Results of the tests of the multivariate assumptions	37
C: Forms	39
Tables and Figures	44

List of Tables

Table I:	Interval means for standardized T-wave amplitude by condition	45
Table II:	Interval means for standardized heart rate by condition	46
Table III:	Grand means per interval for each dependent variable	47
Table IV:	Results of the multivariate tests	48
Table V:	Single df polynomial contrasts for "Intervals" effect	49

List of Figures

Figure 1: Hypothesized trends in arousal as influenced by durational and environmental similarity expectations	50
Figure 2: Idealized cardiac waveform (after Furedy, 1987)	51
Figure 3: Telemetry system used for initial data acquisition and processing	52
Figure 4: Equipment layout as used for digitization of analog EKG signal	53
Figure 5: Plot of grand means of transformed TWA and HR variables by time interval	54

Acknowledgements

I would like to acknowledge the debt I owe to Dr. Peter Suedfeld for his multi-faceted guidance and support. In addition, I would like to thank the other two members of my committee, Dr. Stan Coren and Dr. Robert Hare, for their invaluable assistance.

Thanks are also due to the many members of Dr. Suedfeld's lab; in particular, I wish to express my gratitude to Susan Bluck for her many helpful insights, and to Lucy Stephens for her excellent help at the beginning of this project.

Above all, I would like to thank my wife, Lauren, for being there ... always.

The research endeavours associated with restricted environmental stimulation techniques ("REST"; Suedfeld, 1980) have covered a wide spectrum of psychological interests over the last thirty years. As one peruses the literature, one finds REST researchers investigating the effects of this environment from diverse perspectives as clinical, perceptual, cognitive, and biopsychological orientations (Suedfeld, 1980; Zubek, 1969). The attention paid to each of these areas by REST researchers has, for the most part, been that of an inconstant lover: once the theories or methods have been sampled and played with, interest tends to wane and the area is dropped in favour of newer, more fashionable approaches.

As with many such stories, however, there have been a few low-key but steadfast relationships. Perhaps foremost amongst these interests has been psychophysiology. This has been reflected either explicitly in the form of dependent variables or, implicitly, as "tag-along" variables (those that have been measured simply because they were able to be measured). Perhaps the use of the psychophysiological approach was a natural outcome of the interest in the strange effects reported by subjects (e.g., odd visual sensations, changes in body perception) that were issued from the first sensory deprivation laboratories (Heron, 1957, 1961; but cf. Suedfeld, 1975); yet another notion is that psychophysiology was simply part and parcel of the "shotgun" methodology used in the infancy of any research program centering on a new phenomenon. More likely than either of these explanations, however, is that the initial fascination with psychophysiological measures was a consequence of Donald O. Hebb's (1955) theories regarding the concept of drive and its relationship to nervous system activity. The continued presence of psychophysiology in the REST research field is certainly due in part to the fact that its indices offer easily-quantifiable measures of that nebulous, but pervasive, psychological construct of "arousal".

The concept of arousal has been a central theme in many of the theories produced from restricted environment research. For example, Schultz (1965) invoked a need for cortical arousal, reflected in a drive for sensory variation ("sensoristasis"), as an explanation of much of our behavior. Zuckerman (1969a), building on Hebb's theories, claimed that human beings possessed

a personal "optimal level of stimulation"; this optimal level rested on the concept of general arousal levels.

Both these theories grew out of a body of research that had found that low stimulus environments seemed to affect psychological arousal, often resulting in reports of psychological disturbances (e.g., visual and auditory hallucinations). More recently, however, several studies have reported that such environments have relaxing effects, particularly on heart rate and muscle tone after either flotation tank or water immersion experiences (Forgays and Belinson, 1986; Forgays and McClure, 1974; Lilly, 1977; Suedfeld, Ballard, and Murphy, 1983).

This apparent contradiction may be resolved by noting that the expectations of the subject mediate his or her response(s) to REST (Suedfeld, 1980; Zuckerman, 1969b). The effect of cognitive set has even been shown to have some bearing on physiological functions (Zubek, 1969). Although the focus of many of the studies involving expectancy-set has been the production of negative experiences, it can be easily argued that positive effects could be produced through the same means. This argument may be particularly valid when one considers the influence upon potential subjects of advertising done by present-day commercial flotation centers. Such advertising almost invariably emphasizes the relaxing nature of a session in the tank.

Extreme relaxation represents inactivity; conversely, high arousal is characterized by a high degree of activity. This is true no matter which dimension of relaxation is being measured (e.g., cognitive, affective, physiological), and therefore relaxation and arousal as general concepts seem to be inversely related. Given this, it then follows that if expectations influence arousal, then they must also influence relaxation.

The Third-Quarter Phenomenon

In a recent presentation, Bechtel (1987) noted that the literature on Arctic and Antarctic research stations indicates that certain indices of emotional and behavioral arousal (motivation, morale, and activity) progressively decline from the beginning of a tour of duty. This decline eventually reaches a minimum approximately one-half to three-quarters of the way through the duration. This phenomenon has been reported in missions lasting from two weeks to over a year, suggesting that it is the relative (as opposed to absolute) length of time spent in these

environments that determines when the psychological nadir will occur. Connors, Harrison, and Aikins (1985), in a review of space-station environmental analogues, have made much the same comment: "Substantial evidence suggests that whether the mission lasts days, weeks or months, morale reaches a low point around the one-half to two-thirds mark" (p. 15). Bechtel (1986) has dubbed this informal finding the "third-quarter" phenomenon.

This pattern of response is not limited to low- or restricted-stimulus field settings (such as isolated Arctic and Antarctic bases), nor to strictly psychological measures. Forgays and Belinson (1986) noted a similar trend in the heart rates (HR) of subjects participating in a study of a restricted-stimulus environment, the flotation tank. One of the most significant of their findings is that there appears to be a pattern of HR change that is consistent within and across float sessions. In any given float, HR began at some high point, then decreased a significant amount to a low point approximately mid-way through the session, then rose towards the end of the session to a point somewhere between the first and second HR. With respect to measurements taken across the three float sessions each subject participated in, the average HR was highest for the first session, lowest for the second session, and midrange for the final session. In other words, the manner in which HR changed was the same *within* a single flotation session as it was *across* three flotation sessions.

Taken together, the findings of Bechtel (1986), Connors, Harrison, and Aikins (1985), and Forgays and Belinson (1986) indicate that the third-quarter phenomenon may describe the temporal pattern of at least some aspects of human functioning in restricted stimulation environments. The findings also suggest that this phenomenon is linked to durational expectations of the participants in the mission/project/study (Bechtel, personal communication, December, 1987; Orne, 1986).

Parameters of the Third-Quarter Phenomenon

Consideration of the variables driving the third-quarter curve led to conclusion that it was linked to the idea that people are personal resource managers and planners. We note certain parameters associated with past, present, and future goals, and then allot mental and physical energy to accomplish these goals in the best manner we can devise. This allocation of energies

does not necessarily take the form of one single expenditure of effort; rather, it more likely takes place over time, with active monitoring of both the passage of time, and the amount of energy and type of activities needed to accomplish the task. This structuring of activities with respect to place and time has been developed in detail by Little (1983) and has been noted by Russell and his colleagues (Russell, personal communication, February, 1987; Russell and Snodgrass, 1986; Russell and Ward, 1982).

One of the more salient parameters of any project is the setting in which it takes place: thus, the environment must affect the allocation of psychological and physical resources. Environmental features take many forms; in general these characteristics can be categorized as temporal length, physical features, and informational and emotion-inducing properties.

Entering and leaving a specific environment necessarily demarcates a specific length of time (a "duration"). This time can be divided into two components: the time we have to spend concerned only with the environment and its goals, and the time we have to prepare for the next environment and its goals. The first component I wish to label the involvement component, while the second is clearly a preparation component. These two facets are not "either/or" features; the process nature of their relationship must be emphasized. The transition from involvement to preparation is a gradual procedure, linked to one's awareness of the passing of time, and marked by interspersing of activities associated with both involvement and preparation.

The relationship between involvement and preparation time is also a function of the similarity of environments to one another. It can be argued that entering a dissimilar environment requires mobilization of cognitive, affective, and/or physiological resources. If we pass from a quiet environment to a noisy one, we are faced with processing a greater number of stimuli. Entering a hot environment after spending time in a cold area means that our bodies must compensate for the temperature difference using various physiological systems (e.g., the circulatory system and sweat glands). Given foreknowledge of the characteristics of the next environment, I suggest that human beings attempt to adjust their various functions during the preparation period. Inasmuch as greater degrees of preparation take greater lengths of time, it is

not difficult to see that the amount of time required for preparation is directly related to the dissimilarity of the environment that follows.

Note, however, that if similarity in environments were the only determinant of preparation time, then activity levels would always rise towards the end of the time spent in an environment. This is not necessarily the case; for example, in preparing for sleep, our arousal levels are likely to decrease despite the fact that the room we are to sleep in may be highly dissimilar to our present environment. We see, then, that environmental similarities and environment-related goals both have a bearing on activity levels, determining the degree and direction of the change.

We spend our lives moving through environments; at some point after entering an environment, we must begin to prepare to enter the next. It was hypothesized for this study that the time spent on preparation is based on the goal(s) and similarity of features of the second environment. This led to the conclusion that there is nothing immutable about Bechtel's (1986) third quarter. In fact, patterns of arousal should be highly susceptible to variations in the similarity and goals of any two temporally contiguous environments.

If one regards floating as a personal project (and anecdotal evidence from Dr. Suedfeld's lab certainly indicates that, for a good number of subjects, this may be the case), then the arguments presented in the sections above lead to the following hypotheses:

1. Temporal patterns of arousal levels within any given environment are a function of the dissimilarity between that environment's features and goal(s) and those of the next environment.
2. In situations in which there is a discrepancy between the features and goals of the two environments, the pattern of activity levels will be curvilinear with a single inflection point.
3. The time of the inflection point will be determined by the expected duration of the total time to be spent in the first environment, the similarity of the second environment to the first, and by the effort (physiological, cognitive, and/or affective) needed to accomplish the goal(s) associated with the second environment.

As a corollary of this third hypothesis, one may predict that an environment that requires heightened arousal levels relative to the first will produce a curve whose inflection point will be lower than any other point on the curve; for lowered levels of arousal, the inflection point will be the highest point on the curve.

These hypotheses can be translated into more concrete terms. First, it should be possible to predict the time point at which the lowest level of physiological arousal will occur, based only on the subject's prior knowledge of the float duration and the physical features of the environment that will follow the float. For example, subjects expecting a short float (relative to other subjects' floats) and dissimilar conditions afterward would arrive at their lowest point in the shortest amount of time. If these subjects float longer than they expected, then by extrapolation the trend of the arousal measure will be quadratic, taking the form of a U-curve as their arousal level continues to rise to meet the demands of a new and dissimilar environment. Subjects expecting a long float and similar conditions will take the longest to reach their lowest point and, if the end of their float is prior to the third-quarter mark of their expected duration, then arousal measures will show a linear trend. Finally, if subjects are expecting either a long duration and dissimilar environment, or a short duration and a similar environment, then the low point should occur between the two points mentioned above. These trends are represented in Figure 1.

.....
 Insert Figure 1 about here.

The hypotheses are, of course, predicated upon the notion that subject expectancy influences physiological response. Such a notion has good support in the REST research literature, as it has been shown in prior sensory restriction studies that various ANS and CNS related measures may be affected by expectations (Shepherd, Zubek, and Saunders, 1967; Zubek, 1962; Zubek, Welch, and Saunders, 1964; Zuckerman and Cohen, 1964).

On the measurement of arousal

Arousal has been regarded as either unitary, as in the affective and cognitive literature, or system specific, as in the majority of recent psychophysiological research. The dichotomy of

these two approaches has, at times, seemed to be complete and unresolvable, as summed up in the following statement by McHugo and Lanzetta (1983):

There are no satisfactory solutions to the dilemma posed by the conflicting views short of abandoning the concept of unidimensional arousal. Since at the theoretical (hypothetical construct) level the concept [of unitary arousal] appears viable and useful, compromises must be made. (p. 634)

However, Venables (1984) has questioned how the unitary concept of arousal ever got a foothold in psychology at all. He suggests that so-called "unitary" findings are actually the result of the interaction of several distinct levels of cerebral organization. Venables divides physiological measures into "controlled" and "controlling" variables. Controlled variables are necessary to task performance; hence, they must be kept at a given level in order to perform tasks efficiently. This level is maintained by the controlling variables. In essence, the controlling variables take the brunt of environmental fluctuations. On the other hand, levels of controlled variables change with task demands.

Venables goes on to note that, while certain variables may have some controlling effect, they also have an intrinsic function that takes precedence over this control. For example, many psychophysiological variables represent certain basic functions that must be maintained. As Venables points out, this has implications for the researcher's choice of variables.

... the use of heart rate (HR) as a measure of anger or skin conductance as an index of fear is clearly indirect and is tapping areas of function that have other roles besides indicators of emotional arousal. In particular, these systems have primary vital roles concerned with the maintenance of life and bodily integrity. (p. 139)

The point of all this is that the researcher must be aware of the physiological function of the variables being measured. Further, the argument above suggests that the best measure of a dependent variable is the measure that can be seen to directly mediate the response. In the case of arousal, this means that one must define the type of arousal that is hypothesized to be taking place and then utilize measures that directly reflect that arousal. For example, are the

experiment's manipulations hypothesized to have some bearing on physiological arousal? If so, then HR measurement would be appropriate. On the other hand, if the manipulation is expected to have an effect on the intensity of emotion, HR is a much less direct measure, and hence should not be used as a primary dependent variable.

This "direct linking" of variables to arousal types has implications for the involvement/preparation hypothesis. What is suggested by Venables' arguments is that preparation is best measured by domain-specific variables; that is to say, the dimensions in which two environments (and goals) are dissimilar will produce differential styles of preparation. In the case in which the environment to follow is thought to be demanding due to its physical features, then physiological measures should be affected, as changes in this environmental parameter will require more physical effort. However, if the environment is similar in physical features but not in its "emotional tone", then measures clearly reflecting affective arousal should be the dependent variables. A similar statement could be made for cognitive functioning with respect to environmental information.

These last two domains, affect and cognition, were not dealt with in this study. There were three reasons for this; first among them was the need for interpretable results. When investigating a new theory, the complexity of the study should be kept relatively simple in order to provide as clear a test as possible. Adding two other domains to the test may unnecessarily complicate it.

Second, the logistics of measuring trends in affective and cognitive functioning are not well-suited to the flotation tank. Most of the measures available for charting this activity are pencil-and-paper tasks, which are obviously unsuitable when the subject is floating in a dark environment. Verbal adaptations of these tasks tend to be highly intrusive in the absolute quiet of the tank; use of this method may produce a potential instrumentation effect (Campbell and Stanley, 1963). Any arousal tapped by such measures may be explained as due to the nature of the task itself (Suedfeld, 1980).

Third, those studies that do attempt to measure REST-related affective states and cognitive performance tend to opt for pre- and post-float measures, likely for the reason mentioned

in the paragraph immediately above. This pre/post method makes trend analysis impossible. At least three data points per subject are needed for distinguishing among trends in a within-subjects design; clearly, before-and-after methods yield only two.

As it was, in part, expectations regarding the physical parameters of the environment that were manipulated in this study, measures of physiological arousal were utilized. Three indices of peripheral nervous system activity were chosen; two that represent the autonomic nervous system and one that represents somatic activity.

It was felt that two cardiac measures, heart rate and T-wave amplitude (TWA; see Figure 2), were necessary to properly index autonomic nervous system (ANS) activity. Heart rate is self-explanatory; the T-wave is a component of the electrocardiogram, and is generated by the repolarization of the ventricular mass. Although HR alone has been a standard dependent variable in psychophysiology, the Laceys (Lacey, 1967; Lacey and Lacey, 1970) have shown that, by itself, it can be an unstable indicator of the direction of autonomic system activity.

.....

Insert Figure 2 about here.

.....

Specific information about ANS activity, particularly about the separate contributions of the sympathetic and parasympathetic nervous systems, can be gained by examining HR and TWA together (Heselgrave and Furedy, 1979). Heart rate is influenced by both the parasympathetic and sympathetic nervous system, whereas it has been suggested that the amplitude of the T-wave, being a measure of ventricular activity, is influenced by the sympathetic nervous system alone (Furedy, 1987; Furedy and Heslegrave, 1983; Matyas, 1976; Matyas and King, 1976; Scher, Hartman, Furedy, and Heslegrave, 1986; but see Bunnell, 1980, and Schwartz and Weiss, 1983, for arguments against this measure). Specifically, decreases in TWA indicate an increase in sympathetic activity.

T-wave amplitude has one other benefit as a measure: although, as mentioned above, measures of the cognitive effort expended by floaters are difficult to gather while they are in the tank, TWA may be one variable that permits access to this information (Furedy, 1987; Furedy,

Heslegrave, and Scher, 1984). Attenuation of TWA has been found to be positively related to cognitive effort in solving a mathematical task (Heslegrave and Furedy, 1979).

To give a more complete description of peripheral nervous system activity, it was necessary to take some measure of the arousal of the somatic nervous system. Traditionally, somatic arousal has been measured by quantification of the EMG waveform, which gives an indication of muscle "tension" or activity. It was therefore decided to employ this measure.

Method

Design

Because the phenomenon which originally generated this this investigation (the third-quarter effect) is temporal in nature, it was decided to develop a repeated measures design, utilizing mean HR, TWA, and EMG activity at five contiguous intervals as dependent variables. To test the effect of expectations, a between-subjects component was added, in which a subject's expectations were to be manipulated regarding float duration and the physical features of the tank immediately following his or her float. The resulting design was therefore a 2 (short/long float) by 2 (similar/dissimilar environment) doubly multivariate design, with three repeated measures.

Subjects

Subjects were drawn from a list of flotation tank volunteers, which is compiled on an on-going basis in the lab of Dr. Peter Suedfeld (U.B.C.). The subjects were telephoned according to the order in which they had signed up, beginning from a date approximately six months prior to the study. The initial telephone contact yielded 54 volunteers willing to participate in this study.

All subjects were "novice" floaters (subjects having no prior experience in a float tank). Limiting the sample to these subjects served two purposes: first, naive floaters represent a greater proportion of the general population; second, prior floaters will have experience-anchored expectations that are individualistic and may influence the induction of a common environmental goal (in this study, "relaxation"). As suggested by the involvement/preparation theory outlined above, this goal is a variable that must be controlled.

Initial contact regarding participation in this study was made over the telephone and, after confirming that the individual was still interested in floating, the experimenter gave a general

description of the purposes and procedures of the study. After this, the experimenter asked the person if he or she would mind answering a few questions regarding his or her medical condition. This interview served the twofold purpose of identifying subjects who might be afraid that the experience could be uncomfortable or unsafe, or that may be taking medication that would spuriously affect the autonomic measures. The medical questions also screened for any contagious or infectious diseases. The particular aspect of the medical screen is somewhat redundant, however, in that the tank water is filtered and sterilized after each float session using a three-stage system (particle, bacterial, and viral), which effectively neutralizes any infectious agent. The medical form is administered only as a backup measure; it is felt in the lab that subject safety warrants the extra precautions.

Individuals were dropped as potential subjects if they met any of the following criteria:

1. They were taking psychoactive medication on a regular basis.
2. They had a contagious or infectious condition, whether that condition was currently active or not.
3. They were epileptic or had a history of fainting spells.
4. They currently had hemorrhoids, cold sores, or a rash.
5. They had ever been diagnosed as having abnormal heart activity.
6. They had any allergies that may be activated by the tank environment.
7. They were pregnant.
8. They were asthmatic.
9. They had been treated by a doctor for a serious medical condition in the last three months.

Only one person did not meet the medical criteria. This person was a young woman who was taking tranquilizers under a doctor's supervision.

The experimenter arranged a mutually convenient time for the subject's float session. The subject was then asked to abstain from drinking any beverage that may contain any caffeine (i.e., coffee, tea, hot chocolate, or cola soft drinks) in the period two hours prior to his or her

participation in the study, so that any arousal that might take place in the session could be attributed only to the float conditions.

Of the 53 subjects who passed the initial screening, seventeen had to be dropped after an immediate post-float examination of their data indicated the presence of excessive noise (defined as irregular, noncyclic fluctuations in the signal powerful enough to mask even the relatively strong EKG waveform). Consequently, 36 subjects (eighteen men and eighteen women) were included in the final analyses. The age of these subjects ranged from eighteen to forty years (mean = 24 yrs., mode = 21 yrs.). Because the volunteer list was gathered primarily through responses to posters displayed around the U.B.C. campus, 81% of the individuals accepted as subjects were university students, many of whom were taking at least one psychology course. However, nearly one-fifth of the subjects were employed in a wide variety of non-academic occupations; these subjects had heard of the lab's work through popular science and/or psychology magazines.

Procedure

Immediately following the initial telephone contact, the subject was randomly assigned to one of the four experimental conditions (forty/eighty minute duration by similar/dissimilar environment).

Upon arriving at the lab, subjects were given a brief orientation tour of the facilities. The general functions of each of the pieces of equipment with which they would come into contact (tank, tank/lab intercom, and psychophysiological instruments) were explained in a non-technical manner. In particular, it was pointed out that the hatch on the tank did not lock, so the subjects were quite free to leave the tank at any time they wished. Furthermore, the subjects were informed that an experimenter would be monitoring them via the intercom so that they needed only to speak up should they feel that they wished to communicate with anyone outside the tank for any reason. Besides complying with ethical standards, such orientation procedures have been shown to reduce any apprehension the subject may have with regards to sensory "deprivation" (Suedfeld, 1980). The subjects were also informed of each step of the experimental procedure (pre-float shower, electrode attachment, float, post-float shower). It should be mentioned at this

point that the tank room, shower room, and equipment room adjoin the main part of the lab, so that the subject never had to walk more than a few feet to get from one room to the next.

It was during the orientation tour that the subject was first informed of the experimental condition to which he or she had been assigned. Subjects in Group #1 were told that they would float for forty minutes, after there would be a ten-minute "question period" regarding their float experience. During this question period, conditions would be exactly as they had been during their float (no lights, no sound, same water temperature). Subjects in Group #2 were also told they were to float for forty minutes, but that during the question period the lights in the tank would come on, they might hear some movement from the main lab (ostensibly from "lab workers" now being free to go about their business), and that the water temperature could drop to room temperature as the heating system was shut down. Subjects in Groups #3 and #4 were told the same information as those in Groups #1 and #2, respectively, save that the length of the float was to be eighty minutes. All subjects were told that they would hear some "mellow" music to signal the end of their float and the beginning of the question period.

Following the orientation tour, the subjects were asked to read and complete a set of forms. These included a) a subject information/consent form, which included a list of their rights as a subject, b) a medical information sheet, which asked for information similar to that previously gathered in the telephone interview and, c) a "pre-briefing" paragraph informing the subject that, in general, floating has been found to be a relaxing experience. It was hoped that this last form would introduce a common expectation among the subjects regarding the purpose of "tanking". Random manipulation checks at the end of the subject's participation indicated that the pre-briefing was successful in this respect.

The subject was then asked to shower and do a careful self-inspection for any cuts or abrasions. All such injuries were to be covered with either a liquid bandage or petroleum jelly, supplied by the lab. After the shower, the subject donned a bathrobe, also supplied by the lab, and proceeded to the equipment room.

Electrode Attachment

The experimenter met the subject in the equipment room and proceeded to attach the electrodes. Four electrodes were used in this study. Site placements were as follows:

1. EMG "reference": 2.5 cm. above the nasion.
2. EMG "active": 2.5 cm. above the left eyebrow, directly above the center of the pupil as the subject looked forward.
3. EKG upper: 2.5 cm. below the top of the sternum.
4. EKG lower: 2.5 cm. above the bottom of the sternum.
5. EKG alternative sites: left and right chest, approximately in the middle of a line representing where the deltoid muscle joins the pectoralis major muscle.

These sites were chosen because pilot trials had shown them to remain relatively dry during the course of a one hour float. In addition, the EMG sites are used widely in biofeedback research on relaxation and muscle tension reduction.

The sites were prepared by first wiping the areas with an alcohol swab, then gently abrading using a Biobrade swatch. The sites were given a final gentle abrasion using Redux gel on a cotton swab. Electrode placement was made difficult by the wide variation among the subjects with respect to head shape, body fat, pectoral muscle development, chest hair, and breast type and size. In particular, chest hair (among men) and closely set breasts (among women) created the greatest number of problems. If resistance across the two EKG sites exceeded a previously set maximum allowable level (10,000 ohms), then the alternative sites detailed above were used. These alternative sites were needed for three of the subjects, two males and one female.

Once the electrodes had been successfully attached to the subject and checked for resistance levels, the leads were plugged into the receiver and the experimenter made sure that both the transmitter and receiver were performing properly. Subjects were then instructed as to the proper method for removing the electrodes, so that they were able to do this themselves prior to their post-float shower.

Subjects were reminded at this point about the particular experimental condition they were to experience. After this, they proceeded from the equipment room to the tank and began their float.

After ascertaining (via the lab/tank intercom) that the subject was in the tank and ready to begin the session, the lights in the tank were turned off and the session timer set. Physiological recording began between one and two minutes after the tank lights had been turned out.

Each subject floated for sixty minutes. At the end of the hour, the recording equipment was shut off and music was played into the tank, in accordance with the subject's expectations. However, after the music had played for a few minutes, the subject was informed, once again via the intercom, that he or she could step out and have his or her second shower, as the experimenter would be conducting the question period in the main part of the lab. It should be mentioned that this part of the procedure, if it had not been handled correctly, could have created a bit of concern among some subjects: they assumed that they had somehow done something wrong.

The post-float question period was actually a debriefing and information-exchange session. Subjects were handed a typewritten paragraph that informed them of the true conditions of their float, and the reason it was necessary to use deception in the study. They were then given the opportunity to ask any questions that they may have had, either specifically about the study or about floating in general. Novice floaters typically are eager to discuss their float experience, and the floaters from this study were no exception. Material garnered from these discussions often forms the basis of further studies. Therefore, the anecdotes related to the experimenter were noted for informal analysis at a later date.

Following the debriefing session, subjects were thanked for their participation and told that if, in the future, they had any questions regarding the study, they were to feel free to telephone or visit the lab for information.

Equipment, Data Acquisition, and Scoring

An Ova Systems flotation tank was used as the REST environment in this study. This is a lightproof, sound-attenuated enclosure, approximately 2.75m long by 1.82m wide by 1.52m

high, and shaped much like an egg. The water in the tank is 25 cm deep and is saturated with Epsom salts (47% by volume). This water is heated to $34^{\circ} .5^{\circ} \text{C}$, the temperature of human skin, so that the sensation of contact with the water is greatly reduced. Subjects floated with their face and chest out of the water, breathing normally. Under such conditions, a subject will experience a "zero-gravity" effect on their muscles.

Four Ag/AgCl electrodes were used for signal pickup. These electrodes measure 30 mm in overall diameter with a 16 mm diameter Ag/AgCl contact in the middle of a hard plastic disk. Leads of 90 cm length are permanently attached to the electrode bodies. The electrodes were filled with Redux electrolyte gel and attached to the subject using appropriate double-sided adhesive collars. The leads were then plugged into a transmitter pack, which measures approximately 23 cm by 15 cm by 8 cm when enclosed in its waterproof case. This pack hangs on a flat hook custom built into the inside of the tank above the waterline, at a spot in line with the average floater's head.

Data were gathered using a unique telemetry system designed specifically for the U.B.C. REST laboratory, which allows for transmission, reception, and cursory analysis of psychophysiological signals (see Figure 3). The signals are picked up using electrodes and converted, in the transmitter, to "pulse-width modulated" (PWM) radio signals. These PWM signals are received by an antenna two feet away from the tank, and passed along to the radio receiver, in much the same fashion as an FM receiver picks up a local radio station. The raw PWM signals are then recorded on standard VHS-format video tape, using a Panasonic video tape recorder. At this point, on-line data acquisition ends.

.....
 Insert Figure 3 about here.

At this stage, the stored signal can be viewed on a computer screen and/or passed along to a signal integrator, depending on the type of analysis required. In this study, the EMG waveform was to be integrated and the EKG waveform was to be scored in its wave state. From the integrator, the EMG signal was to be sent to a Cyborg Model 91 ISAAC unit attached to the lab's

Apple IIe microcomputer. The computer, running a Labsoft CADRE (Computer Assisted Data Reduction) program, would then store the integrated signal as a series of numbers. These numbers could be then be transferred to a mainframe computer for analysis.

Although the Labsoft software has a wide range of applications, it was decided that equipment and software available in the psychophysiological laboratory of Dr. Robert Hare would provide the clearest and most convenient scoring of T-wave amplitude and heart rate. The EKG waveforms were digitized in Dr. Hare's lab using, for the most part, a hybrid of UFI and Beckman instruments (see Figure 4). The Panasonic video tape recorder and UFI pulse-width demodulator were linked to a Beckman Type 9806A coupler. The signal was then amplified through a Beckman Type 461D pre-amplifier and Type 411 amplifier. The pre-amplifier was set to DC input, with its frequency switch in Position 2 and pre-amplification at .1 V/mm. The amplifier was set to a multiplication factor of one, with a high frequency cutoff of 30 Hz. The settings for these modules were arrived at through trial-and-error and are somewhat arbitrary, as the UFI demodulator has an on-board pre-amplifier of its own and its output is difficult to determine when it is not used in conjunction with other UFI modules.

.....
Insert Figure 4 about here.
.....

The signal coming out of the Beckman equipment was digitized using a custom-built analog-to-digital (A/D) unit. This equipment proportionally scales an incoming signal in A/D units ranging from a minimum of 0 to a maximum of 4096.

The acquisition of the digitized signal was performed using a customized Fortran program (see Appendix A) running on a Compaq 286 microcomputer. Sampling rate was set to 100 samples/second, with an epoch lasting five seconds. Epochs began on a randomly determined second of each minute; the list of random numbers used for this purpose is found embedded in the Fortran sampling program. None of the numbers exceeded fifty seconds, as the acquisition program needed at least five seconds to write the acquired information to the hard disk used for storage.

Once written to disk, the signal was digitally filtered using the EEG Analyst program, designed by Paradigm Inc. (Vancouver, B.C.). This program was designed to be used primarily for the viewing and analysis of EEG signals, but served remarkably well as an accurate tool for probing EKG waveform components. It also allows the luxury of user-defined filters; the amount of noise in the signal (resulting from the ambient electrical noise picked up in the telemetry unit) required a specific lowpass filter. Once again through trial-and-error, it was determined that a lowpass filter of 20 Hz (window = 51 samples) allowed the signal to be viewed with recognizable components and the least amount of noise.

T-wave amplitude was scored using criteria similar to those developed by Matyas and King (1975). Matyas and King defined TWA as the difference between the P-Q isoelectric interval and the peak of the T-wave. However, the electrode sites in this study compressed the P and Q waves horizontally along the EKG waveform so that isoelectric intervals were present only in the signals of those three subjects who had had alternate site placements. Fortunately, the filtration used in the signal conditioning produced a notch in the P wave; the lowest point of this notch approximated the level of the missing interval. This was determined by comparing the notched P waves and P-Q intervals available in the three alternate site subjects.

Inter-beat intervals (IBI's) were scored using the "Peaks" subroutine in the EEG Analyst program; these IBI's were then numerically converted to heart rates. IBI's, the most sensitive measure of heart rate fluctuation, were used as the basis of heart rate assessment.

Results

Data Reduction

The EMG and EKG waveforms were visually inspected on a computer screen to judge their ability to be scored properly. It soon became apparent that the rapid and non-cyclic nature of noise present in the signal prohibited the analysis of the EMG signal. The source of this noise is a mystery; all transmission lines were shielded, and no faulty connections could be found in the equipment.

If the noise had been of a regular frequency (e.g., 60 Hz "line" noise), a notch filter could have been used to remove the unwanted components. Additionally, the noise, though minor in comparison to the strong EKG signal, was of such amplitude that it simply overwhelmed the relatively weak EMG signal received from the subject's frontalis muscle. For these reasons, it was decided to drop the EMG as a dependent variable.

Each subject's TWA's were averaged across the five-second epochs. Because of individual differences in heart rate, subjects varied widely as to the actual number of T-waves that could be scored: As few as two, and up to a maximum of four, TWA's per epoch were used. Generally, this yielded sixty mean TWA's per subject; in a few cases, however, an entire epoch was rendered unscorable due to a surge in the noise level.

Three possible methods were considered for dealing with these missing values. First, the value could be "ignored", and the twelve-minute mean that would eventually become a datum in the final analyses (see below) would actually be an eleven- or ten-minute mean. Second, the missing value could be replaced by the average of the scores immediately preceding and following it. Third, the missing value could be set to the average value for the subject.

The first and second options were ruled out on both mathematical and theoretical grounds. Reducing the number of data entered into the (nominally) twelve-minute mean created an unwanted weighting of the average towards either the beginning or the end of the twelve-minute

period, and could have set up false and unwanted dependencies in the within-subject measures. The second method rested upon the assumption that a linear relationship joined all the means within any epoch. As it was exactly this sort of trend over time that this study was designed to investigate, making such an assumption was not justified.

In the absence of other information, the expected value ("best guess") of a random draw from a set of numbers is the average of those numbers. Using this value, in this case the subject's own grand mean TWA, allowed a slight conservative bias to be introduced while maintaining the number of data upon which the twelve-minute mean was based.

It was decided to standardize the measures within each subject before the twelve-minute means were calculated. Changing the TWA's and HR's to Z-score form allowed a direct, "metric-free" comparison of the activity of the two dependent variables. In addition to this, transforming each subject's response using his or her own mean and standard deviation yielded a variable based on the subject's performance alone. The variation in lability among subjects with regard to any given dependent measure is a common finding in psychophysiological research; using the subject as his or her own baseline is often a distinct advantage.

Finally, the data were averaged across the twelve-minute intervals, yielding five means that were used as the data points in the analyses described below.

Heart rate data were treated in the same manner as the TWA data, including the substitution procedure for missing data. The means for the standardized TWA by interval are presented in Table 1; Table 2 gives the means by interval for standardized heart rate. The grand means for each dependent variable in each interval, in both original and standardized form, are presented in Table 3.

.....
 Insert Table 1, Table 2 and Table 3 about here.

A multivariate analysis of variance (MANOVA) approach was adopted as the statistical procedure in this study. The benefits of using this procedure versus multiple univariate repeated-measures analyses have been detailed elsewhere (O'Brien and Kaiser, 1985), but two points are particularly relevant to this study. First, the methodological design was inherently multivariate. Second, the use of MANOVA avoids the sphericity assumptions necessary, but usually unattainable, in univariate analyses. For a complete synopsis of the procedures used in testing the appropriate assumptions for this doubly multivariate analysis, please see Appendix B.

In terms of the specific test of the multivariate hypotheses, it was decided to use Pillai's trace. This test has been shown to be reasonably robust to violations of multivariate assumptions, while offering good power where the underlying structure of the data is diffuse (Olson, 1974, 1976).

Multivariate Analysis

Following the testing of the necessary assumptions, the data were submitted to a doubly-multivariate MANOVA. Two statistical packages were used: The primary analyses were carried out using SYSTAT, a relatively new and versatile package that yields a very uncluttered output; the second was SPSS^x (version 2.2), available through the main computing facilities at the University of British Columbia. This latter package was used to confirm the analysis performed with SYSTAT. Although SYSTAT is flexible, it has no direct method for testing doubly-multivariate models; rather, the procedure requires an extensive use of contrast matrices. Confirmation of the results from an independent package was therefore considered prudent. The two sets of output agreed to three decimal places. The command files used for each package can be found in Appendix A.

The results were quite striking, if only in their near-total disconfirmation of the involvement/preparation theory in the flotation tank. These results are summarized in Table 4. As may be seen, expectations regarding duration of the float and similarity of the environment did not significantly affect the subjects' overall response. This held for both the between- and within-subjects hypothesis tests.

.....
Insert Table 4 about here.
.....

It was only when one collapsed the data across both between-subjects factors that a significant result emerged. The Intervals result represents a multivariate test of eight separate hypotheses: TWA and HR were independently tested for four trends each (linear, quadratic, cubic, and quartic), with each test based on all thirty-six subjects. The multivariate statistic associated with these planned orthogonal contrasts indicated that at least one, and possibly more, of the dependent measures showed an extremely strong trend ($F(8,25)=14.517$, $p < .001$). It was therefore decided to investigate which trend(s) accounted for the multivariate result by probing the Intervals effect using univariate analyses, adopting a conservative significance level of $p < .005$.

The results of the univariate analyses can be found in Table 5. It was immediately apparent that no single trend or measure caused the significant multivariate result. The TWA measure showed a strong linear trend and, to a somewhat lesser extent, a cubic trend. The HR also indicated a strong linear component, but this pattern was influenced by a quadratic trend.

.....
Insert Table 5 about here.
.....

To understand better how these trends interacted, a graph of the means for each DV in each interval was constructed (Figure 5). At first glance, the curve describing the standardized heart rate appears to be a "third-quarter" curve, beginning at a high point, dropping smoothly to a minimum after the midpoint, then rising towards the end; in contrast, the standardized TWA rises immediately from the beginning, reaches a maximum in the interval just prior to the midpoint, then drops until it reaches a minimum in the fifth and final interval. It should be noted, however, that although the HR trend resembles a third-quarter curve, a Bonferroni dependent samples t-test conducted using the fourth and fifth interval data did not reach statistical significance ($t(32) = 1.56$, $p > .10$; one-tailed).

.....
 Insert Figure 5 about here.

Discussion

The results clearly offer no support for the involvement/preparation theory, at least in its applicability to physiological functioning in the tank. The main test of the theory was performed in the between-groups section of the research design, and it is obvious from the statistical analyses that differences in either environmental similarity or durational expectations had no significant effect on patterns of T-wave amplitude or heart rate.

The successful manipulation of durational and environmental expectations was confirmed in a post-float manipulation check embedded in the debriefing interview. How, then, can we explain the lack of effect of these expectations, when several arguments and findings have suggested that such manipulations should have had some influence on cardiac activity?

The most obvious possibility is that we simply do not take into account such ideas as involvement and preparation with respect to environmental parameters and goals. Simply stated, the basic premise of the involvement/preparation hypothesis is incorrect, and arousal patterns in general are not influenced by such factors.

Examining the trends in the data, the initial rise in TWA between Intervals 1 and 2 suggests that sympathetic nervous system activity is decreasing. One may suspect that

autonomic nervous system arousal is generally decreasing, and this seems to be supported when one looks at the decrease in heart rate between these two points. However, TWA begins to attenuate after Interval 2 and does not increase again, leading us to believe that SNS activity is increasing during all intervals but the first. When one turns to HR for corroboration of this increase of activity, it cannot be found. In fact, HR decreases from Interval 2 to Interval 4, rising insignificantly in Interval 5. This pattern is in opposition to the TWA trend, suggesting that the two measures are under the control of different systems.

It is commonly acknowledged in the relevant literature that HR is controlled by both the sympathetic and parasympathetic nervous systems (Larsen, Schneiderman, and DeCarlo Pasin, 1986). As mentioned toward the beginning of this paper, it has been argued that TWA is primarily influenced by the sympathetic nervous system. Regarding the TWA and HR responses with this in mind, one can see that as SNS activity increases (marked by TWA attenuation), a greater increase in PNS activity must have accompanied it in order to bring about the decrease in HR. Rather than a lowering of physiological arousal levels, the experience of floating is associated with a rise in activity of both sub-systems of the ANS. This is not to say that the unique experience of floating produces such a response; an obvious alternative explanation is that simply laying quietly for an hour will produce the same effect.

Evidence from the informal debriefing interviews indicates that the tank is perceived by a large number of novice floaters as an explorative experience, as well as an environment in which one may work out short- and long-term difficulties one has been experiencing; therefore, contemplation may be the reason for the attenuated TWA. If we consider that contemplative behavior requires cognitive effort, then the findings regarding TWA indicate that this behavior is on the increase twelve minutes after the subject enters the tank. Exploration and introspection are the orders of the day: after all, where else can one find so novel an environment, and one in which interruption of one's thoughts is so unlikely?

Interestingly, one of the more common findings in the debriefing interview was that one could not maintain an extended train of thought while in the tank. In a dream-like manner, subjects slipped from one thought to another, never fully finishing a thought or reaching a

conclusion, even though some had firmly intended to solve certain problems (e.g., difficulties in a personal relationship, career plans, personal goal-planning). Whether it was the novelty of the environment that prevented linked thinking, or perhaps an overwhelming sense of relaxation that simply blocked extended information processing, is a matter of conjecture. What does seem likely is that such effort may have led to the trends exhibited by both HR and TWA in this study.

Alternatively, subjects could have been generating increasingly more complex images and thought patterns as their time in the tank wore on. It has been suggested that TWA attenuation is a potential marker of "a more selective and complexly organized set of cognitive processes, requiring higher levels of selective functioning or 'wakefulness'..." (Cacioppo, Petty, and Morris, 1985 p.381;). Perhaps passing from one thought to the next brought about the chance to experience more interesting images; either by learning how to use the tank's unique environment for mental exploration, or through a lowering of mental blocks, the subject became more involved in the world of his or her mind. It may not be that the level of internal stimulation increases: we may simply become better at detecting, and more interested in, the thoughts that are screened out by our interaction with the environment in everyday life.

Turning to the third-quarter effect, the results do not show support for its existence in ANS responses to the tank. While it is true that HR did "bottom out" in the fourth quintile, the lack of a significant difference between the fourth and fifth intervals indicates that the rise in the fifth quintile could have been due to random fluctuation. It appears that HR simply reached a nadir shortly after the midpoint of the float. Even if one argues that whatever drives the third-quarter effect was actually operating in the tank, it is apparent that its influence was of insufficient strength to direct the HR and TWA response. It may well be that the third-quarter phenomenon applies only to those non-physiological measures directly reflecting emotion, motivation, and morale.

Yet another possibility is that the duration of the tank session was too short to produce a third-quarter curve. It is entirely conceivable that given a sufficiently long time in the tank, the curve may have begun to rise.

The deep sense of relaxation and well-being reported by most subjects in the post-float interview is most likely associated with decreased muscle tone, as manifested in the lower demand on the heart. Due to the difficulties detailed in the Results section, direct measures of muscle activity were rendered unusable; firm statements regarding the state of the musculature will have to be reserved for a future study. However, assuming for the moment that the subjects reached "maximum" muscle relaxation, the concurrent high level of cognitive activity (indicated by TWA attenuation) allowed the subjects the rare experience of being physically relaxed and cognitively active at the same time.

The results of the two available measures indicate that the tank may be useful as a relatively quick method of relaxation. The key to successfully using the tank is in specifying what one wishes to derive from the experience. If straight physical relaxation is the goal, then a short stay of thirty to forty minutes should suffice. This is particularly good news to those who may wish to employ the tank as a precursor to physiotherapy or massage. If one wishes to experience the potential psychological benefits of tank-related cognitive activity, then a longer float session may be in order. Research examining the temporal patterning of cardiovascular functioning and levels of muscle activity of human beings, in both the flotation tank and a control environment, is definitely in order.

In summary, this study has shown that measures of autonomic nervous system activity seem to be unaffected by expectations of float duration or expectations of the type of environmental conditions that are to follow the float. Additionally, the trends of T-wave amplitude and heart rate do not follow a third-quarter curve, as described by Becthel (1987). What does seem apparent is that the flotation tank is a physically relaxing environment that may promote cognitive activity. The form and pattern of this activity could form the subject matter of further research, as could the effect of lengthier flotation sessions on patterns of ANS activity.

References

- Bechtel, R. (1987, August). The third-quarter phenomenon. In A.A. Harrison and M.M. Connors (Chairs). The human experience in Antarctica: application to life in space. Symposium conducted in San Jose, CA.
- Bunnel, D.E. (1980). T-wave amplitude and P-Q interval: Relationships to non-invasive indices of myocardial performance. Psychophysiology 17(6): 592-597.
- Cacioppo, J.T., Petty, R.E., and Morris, K.J. (1985). Semantic, evaluative, and self-referent processing: Memory, cognitive effort, and somatovisceral activity. Psychophysiology 22(4): 371-384.
- Campbell, D.T., and Stanley, J.C. (1963). Experimental and quasi-experimental designs for research. Chicago: Rand McNalley.
- Connors, M.M., Harrison, A.A. and Akins, F.R. (1985). Living aloft: Human requirements for extended spaceflight. (NASA Publication No. SP-483). Washington, D.C.: U.S. Government Printing Office.
- Forgays, D.G. and Belinson, M.J. (1986). Is flotation isolation a relaxing environment? Journal of Environmental Psychology 6: 19-34.
- Forgays, D.G. and McClure, G.N. (1974). A direct comparison of the effects of the quiet room and water immersion isolation techniques. Psychophysiology 11(3): 346-349.
- Furedy, J.J. (1987). Beyond heart rate in the cardiac psychophysiological assessment of mental effort: The T-wave amplitude component of the electrocardiogram. Human Factors 29(2): 183-194.
- Furedy, J.J. and Heslegrave, R.J. (1983). Consideration of recent criticisms of the T-wave amplitude index of myocardial sympathetic activity. Psychophysiology 20(2): 204-211.
- Furedy, J.J., Heslegrave, R.J., Scher, H. (1984) Psychophysiological and physiological aspects of T-wave amplitude in the objective study of behavior. Pavlovian Journal of Biological Science 19(4): 182-194.
- Hand, D.J. and Taylor, C.C. (1987). Multivariate analysis of variance and repeated measures. Chapman and Hall: London.
- Hebb, D.O. (1955). Drives and the C.N.S. (Conceptual Nervous System). Psychological Review 62: 243-254.
- Heron, W. (1957). The pathology of boredom. Scientific American 196: 52-56.
- Heron, W. (1961). Cognitive and physiological effects of perceptual isolation. In P. Solomon et al. (Eds.) Sensory deprivation. Cambridge, Mass.: 6-33.
- Heslegrave, R.J. and Furedy, J.J. (1979). Sensitivities of HR and T-wave amplitude for detecting cognitive and anticipatory stress. Physiology and Behavior 22(1): 17-23.

- Lacey, J.I. (1967). Somatic response patterning and stress: some revisions of activation theory. In M.H. Appley and R. Trumbull (Eds.). Psychological stress: Issues in research. New York: Appleton-Century-Crofts. pp. 14-44.
- Lacey, J.I., and Lacey, B.C. (1970). Some autonomic-central nervous system interrelationships. In P. Black (Ed.). Physiological correlates of human emotion. New York: Academic Press. pp. 205-227.
- Larsen, P.B., Schneiderman, N., and DeCarlo Pasin, R. (1986). Physiological bases of cardiovascular psychophysiology. Chapter in M.G.H. Coles, E. Donchin, and S.W. Porges (Eds.). Psychophysiology: systems, processes, and applications. New York: Guildford.
- Lilly, J.C. (1977). The deep self. New York: Simon & Schuster.
- Little, B. (1983) Personal projects: a rationale and method for investigation. Environment and Behavior 15(3): 273-309.
- Loeb, G.E. and Gans, C. (1986). Electromyography for experimentalists. Chicago: The University of Chicago Press.
- Matyas, T.A. (1976). T-wave amplitude stability during sinus arrhythmia in the resting man. Physiology and Behavior 16: 115-117.
- Matyas, T.A. and King, M.G. (1976). Stable T-wave effects during improvement in heart rate control with biofeedback. Physiology and Behavior 16: 15-20.
- McHugo, G.J., and Lanzetta, J.T. (1983). Methodological decisions in social psychophysiology. In J.T. Cacioppo and R.E. Petty (Eds.). Social psychophysiology: A sourcebook. New York: Guildford.
- O'Brien, R.G., and Kister Kaiser, M. (1985). MANOVA method for analyzing repeated measures designs: An extensive primer. Psychological Bulletin 97(2): 316-333.
- Olson, C.L. (1974). Comparative robustness of six tests in multivariate analysis of variance. Journal of the American Statistical Association 69: 894-908.
- Olson C.L. (1976). On choosing a test statistic in multivariate analysis of variance. Psychological Bulletin 83: 579-586.
- Orne, M. (1986, August) Demand characteristics in REST and health psychology. Paper presented at the third annual meeting of the International REST Investigators Society, New York, New York.
- Russell, J.A. and Snodgrass, J. (1986). Plans and the environment. In D. Stokols and I. Altman (Eds.), Handbook of environmental psychology. New York: Wiley.
- Russell, J.A., and Ward, L.M. (1982). Environmental psychology. Annual Review of Psychology 33: 651-688.
- Schultz, D.R. (1965). Sensory restriction. New York: Academic Press.
- Schwartz, P.J. and Weiss, T. (1983). T-wave amplitude as an index of cardiac sympathetic activity: A misleading concept. Psychophysiology 20(6): 696-701.

- Sher, H., Hartman, L.M., Furedy, J.J., and Heselgrave, R.J. (1986). Electrocardiographic T-wave changes are more pronounced in Type A than in Type B men during mental work. Psychosomatic Medicine 48(3-4): 159-166.
- Shepherd, J.M., Zubek, J., and Saunders, M.G. (1967). EEG changes during sensory and perceptual deprivation studies. Electoencephalography and Clinical Neurophysiology 22: 191.
- Suedfeld, P. (1969). Theoretical formulations II. In J. Zubek (Ed.) Sensory deprivation: Fifteen years of research. New York: Appleton-Century-Crofts.
- Suedfeld, P. (1975). The benefits of boredom: Sensory deprivation reconsidered. American Scientist 63(1): 60-69.
- Suedfeld, P. (1980). Restricted environmental stimulation: Research and clinical applications. New York: Wiley.
- Suedfeld, P., Ballard, E.J., and Murphy, M. (1983). Water immersion and flotation: From stress experiment to stress treatment. Journal of Environmental Psychology 3: 147-155.
- Tabachnick, B.G. and Fidell, L.S. (1983). Using multivariate statistics. Harper and Row: New York.
- Venables, P.H. (1984). Arousal: an examination of its status as a concept. In M.G.H. Coles, J.R. Jennings, and J.A. Stern (Eds.). Psychophysiological perspectives: Festschrift for Beatrice and John Lacey. New York: Van Nostrand Reinhold.
- Zubek, J. (1964). Behavioral and EEG changes after 14 days of perceptual deprivation. Psychonomic Science 1: 57-58.
- Zubek, J. (1969). Sensory deprivation: fifteen years of research. New York: Appleton-Century-Crofts.
- Zubek, J., Welch, G., and Saunders, M.G. (1962). Electroencephalographic changes after 14 days of perceptual deprivation. Science 139: 490-492.
- Zuckerman, M. (1969a). Theoretical formulations: I. In J. Zubek (Ed.) Sensory deprivation: Fifteen years of research. New York: Appleton-Century-Crofts.
- Zuckerman, M. (1969b). Variables affecting deprivation results. In J. Zubek (Ed.) Sensory deprivation: Fifteen years of research. New York: Appleton-Century-Crofts.
- Zuckerman, M., and Cohen, N. (1964) Is suggestion the source of reported visual sensations in perceptual isolation? Journal of Abnormal and Social Psychology 68: 655-660.

1. Fortran analog-to-digital acquisition program

\$NODEBUG

\$STORAGE:2

INTEGER*2 OUTPUT(51200), BLO(60)

DATA BLO /46,29,39,26,18,44, 7,48,51,18,30,51,38,

+ 16,25,36,40,18, 2, 5,24,31,38,41,21,29,10,24,27,

+ 45, 9, 5,41, 3, 2,25,28, 8,23,23,20,24,48,11, 8,

+ 44, 0,21,38,24,35,14,18, 9,39,33,45/

NTRIAL=60

IRATE=100

NSAMPL=500

ICHAN=1

NCHAN=1

CALL TRESET

CALL PTOPEX ('D:EEG.RAW ', NTRIAL, NCHAN, NSAMPL)

CALL ADSPEC (2, IRATE, ICHAN, NCHAN)

ITIME2=0

WRITE (*,15)

15 FORMAT (/,' [ENTER] to begin signal collection',/)

READ(*,*)

DO 100 J=1, NTRIAL

CALL TSTART

ITIME=BLO(J)*100

31 CALL TREAD(1,ICLK)

IF (ICLK .LT. ITIME) GOTO 31

CALL ADBLOC (OUTPUT, NSAMPL, ISYNCH, IRET)

IF (IRET .NE. 0) THEN

```

        WRITE (*,*) 'A/D initialization error '
        GOTO 9999
    ENDIF
13  CONTINUE
        IF (ISYNCH. LT. NSAMPL) GO TO 13
        IRET=ADHALT()
        WRITE(*,*)'IRET FROM ADHALT=',IRET
        IF(IRET.NE.0) GOTO 9999
        WRITE(*,25) J, ITIME, ITIME2
25  FORMAT (' BLOCK = ', 3I6,\)
        DO 18 K=1,NCHAN
            CALL PUTREC (J, K, OUTPUT((K-1)*NSAMPL+1))
18  CONTINUE
32  CALL TREAD(1,ITIME2)
        IF (ITIME2 .LT. 6000) GOTO 32
100 CONTINUE
9999 CALL PTCLOS
        STOP
        END

```

2. Systat command file: Doubly multivariate analysis.

```

USE B:STD
CAT D=2,E=2
MOD T1,T2,T3,T4,T5,H1,H2,H3,H4,H5=CONSTANT+D+E+D*E/REPEAT=2,5
OUTPUT B:TRASH
EST
OUTPUT B:MANOVA
HYPOTHESIS
NOTE 'DURATION TEST'

```

EFFECT=D

CMATRIX

1 1 1 1 1 0 0 0 0 0

0 0 0 0 0 1 1 1 1 1

TEST

HYPOTHESIS

NOTE 'ENVIRONMENT TEST'

EFFECT=E

CMATRIX

1 1 1 1 1 0 0 0 0 0

0 0 0 0 0 1 1 1 1 1

TEST

HYPOTHESIS

NOTE 'INTERACTION TEST'

EFFECT=D*E

CMATRIX

1 1 1 1 1 0 0 0 0 0

0 0 0 0 0 1 1 1 1 1

TEST

HYPOTHESIS

NOTE 'INTERVALS TEST'

EFFECT=CONSTANT

AMATRIX

1 0 0 0

CMATRIX

-2 -1 0 1 2 0 0 0 0 0

2 -1 -2 -1 2 0 0 0 0 0

-1 2 0 -2 1 0 0 0 0 0

1 -4 6 -4 1 0 0 0 0 0

0 0 0 0 0 -2 -1 0 1 2

0 0 0 0 0 2 -1 -2 -1 2

0 0 0 0 0 -1 2 0 -2 1

0 0 0 0 0 1 -4 6 -4 1

TEST

HYPOTHESIS

NOTE 'DURATION BY INTERVALS TEST'

EFFECT=CONSTANT

AMATRIX

0 1 0 0

CMATRIX

-2 -1 0 1 2 0 0 0 0 0

2 -1 -2 -1 2 0 0 0 0 0

-1 2 0 -2 1 0 0 0 0 0

1 -4 6 -4 1 0 0 0 0 0

0 0 0 0 0 -2 -1 0 1 2

0 0 0 0 0 2 -1 -2 -1 2

0 0 0 0 0 -1 2 0 -2 1

0 0 0 0 0 1 -4 6 -4 1

TEST

HYPOTHESIS

NOTE 'ENVIRONMENT BY INTERVALS TEST'

EFFECT=CONSTANT

AMATRIX

0 0 1 0

CMATRIX

-2 -1 0 1 2 0 0 0 0 0

2 -1 -2 -1 2 0 0 0 0 0

-1 2 0 -2 1 0 0 0 0 0

1 -4 6 -4 1 0 0 0 0 0

0 0 0 0 0 -2 -1 0 1 2

0 0 0 0 0 2 -1 -2 -1 2

0 0 0 0 0 -1 2 0 -2 1

0 0 0 0 0 1 -4 6 -4 1

TEST

HYPOTHESIS

NOTE 'DURATION BY ENVIRONMENT BY INTERVALS TEST'

EFFECT=CONSTANT

AMATRIX

0 0 0 1

CMATRIX

-2 -1 0 1 2 0 0 0 0 0

2 -1 -2 -1 2 0 0 0 0 0

-1 2 0 -2 1 0 0 0 0 0

1 -4 6 -4 1 0 0 0 0 0

0 0 0 0 0 -2 -1 0 1 2

0 0 0 0 0 2 -1 -2 -1 2

0 0 0 0 0 -1 2 0 -2 1

0 0 0 0 0 1 -4 6 -4 1

TEST

3. SPSS^x command file: Doubly multivariate analysis.

TITLE MANOVA: DOUBLY MULTIVARIATE TREND ANALYSIS (MASTERS)

DATA LIST FILE=A:STD3615

/ID 1-3(A) DUR 5 ENV 7 MF 9 AGE 11-12 T1 15-21 T2 23-29 T3 31-37

T4 39-45 T5 47-53 H1 1-10 H2 12-21 H3 23-32 H4 34-43 H5 45-54

VARIABLE LABELS ID 'SUBJECT ID'

DUR 'DURATION'

ENV 'ENVIRONMENT'

MF 'SUJECT GENDER'

VALUE LABELS DUR 1 '40 MIN.' 2 '80 MIN.'

/ENV 1 'DISSIM.' 2 'SIMILAR.'

LIST VARIABLES ALL

FREQUENCIES AGE T1 T2 T3 T4 T5 H1 H2 H3 H4 H5

/HISTOGRAM

/STATISTICS=ALL

REGRESSION VARIABLES=T1 T2 T3 T4 T5 H1 H2 H3 H4 H5 DUR ENV

/DEPENDENT=DUR ENV

/METHOD=ENTER

/RESIDUALS=OUTLIERS(ZRESID SRESID SDRESID MAHAL COOK) HISTOGRAM

/CASEWISE=PLOT

MANOVA T1 T2 T3 T4 T5 H1 H2 H3 H4 H5 BY DUR(1,2) ENV(1,2)

/WSFACTOR=TIME(5)

/MEASURE=T H

/CONTRAST(TIME)=POLYNOMIAL

RENAME=TCONS TLIN TQUAD TCUBE TQUAR HCONS HLIN HQUAD HCUBE

HQUAR

/WSDESIGN/PRINT=CELLINFO(MEANS COR SSCP) TRANSFORM SIGNIF(AVERF)

DESIGN(OVERALL) ERROR(COR) PRINCOMP(COR) PARAMETERS(ESTIM CORR)

/PLOT=CELLPLOTS NORMAL

/METHOD=SSTYPE(UNIQUE)

/ANALYSIS(REPEATED)

/DESIGN

Appendix B: Results of the tests of the multivariate assumptions.

No matter how robust a test may be, it is still affected to some degree by violations of its assumptions. Therefore, the data matrix was checked for multivariate normality, homoscedasticity, linearity, multicollinearity, and influential outliers prior to the major analysis.

The assumption of multivariate normality for the repeated-measures (RM) MANOVA procedure requires that the sampling distribution be normally distributed at every level of the between and within subjects factors; this assumption, at least at present, is untestable (Hand and Taylor, 1987). Barring the availability of such a test, one may assess the normality of each of the dependent variables; although normally distributed DV's do not guarantee multivariate normality, skewed dependent variables are a sure indication of a violation. This assessment was done by finding the Z-score equivalent of the skews for each cell. The formula (given in Tabachnick and Fidell, 1983) is

$$Z_{\text{skew}} = \frac{\text{Skew} - 0}{\text{S.E.}_{\text{skew}}} \quad \text{where } \text{S.E.}_{\text{skew}} = \frac{6}{N}$$

and N is the number of observations.

The criterion for normal distribution was a Z_{skew} score less than 2.326 ($p < .01$); only one of the transformed variables exceeded this criterion (the skew for all HR data in interval four).

The assumptions of linearity and homoscedasticity were assessed by examining the scattergrams of each pair of dependent variables. None of these showed any gross departure from a linear relationship, nor did the plots indicate overt heteroscedasticity. Multiple regression analyses (MRA) were employed to examine possible multicollinearity in the data set. The method used is given in Tabachnick and Fidell (1983; p.83); essentially it involves comparing each DV against a linear combination of all the others. A large squared multiple correlation is indicative of multicollinearity. However, this method was developed for MANOVA's in which there were no repeated measures, as it assumes there are no inherent relationships among all dependent variables. When the same measures are taken again and again over time, this is clearly not the case. Therefore, a modified version of the MRA method was used. Each interval level of TWA was tested against a linear combination of HR, and the same was done for each level of HR

against the TWA intervals. Not one of the multiple R^2 fell below a probability of .10, thereby indicating that the assumption of multicollinearity held, at least as far as it can be tested for in repeated-measures MANOVA.

Outliers were identified using calculations of Mahalanobis' distance, and their potential influence assessed via Cook's distance. When the results of these two tests were considered in combination, there appeared to be no outliers that could be considered harmfully influential.

Floatation Consent Form

As a volunteer for this study, you should know what this part of the project is going to be like. You will spend up to one hour floating in warm, salt water in a dark, quiet floatation tank. You are instructed to remain reasonably quiet while in the water. That means you are to avoid whistling, singing, talking to yourself, and the like. You are also asked to refrain from excessive movement while you are floating.

Before and after the floatation session you will be asked to shower thoroughly and to wash your hair. Earplugs will be supplied for use during your float. At all times when you are in the tank, there will be a monitor next door who will listen through the intercom to make sure that you are all right and that you are not moving around too much or talking to yourself and so on. From time to time you may be asked questions about how you are feeling.

Floatation tanks are used commercially for relaxation. Research indicates that most floaters have found the experience very pleasant. However, if you should find the situation unpleasant, you may end the experiment simply by notifying the monitor over the intercom and then stepping out of the tank. Doing this does not reflect upon you in any way. Some people just find such a situation unappealing and there is no reason why they should force themselves to continue in it.

Dr. Peter Suedfeld
Project Director

I have read the Floatation Consent Form and agree to participate in the project as described above.

Date: _____ Signature: _____

Printed Name: _____ Birth Date: _____

Phone Number: _____ Subject #: _____

Psychophysiology Study I

S# _____

**Please note that answers to the following questions are for experimental use only and will be considered confidential.

Medical Intake Form

Have you been examined and/or treated by a physician within the last year? Yes No

Have you been seriously ill? Yes No

When? _____ With what? _____

Have you ever been hospitalized? Yes No

For what? _____

Do you wear a medic alert? Yes No For? _____

Do you have any contagious conditions? Yes No

Are you taking any medication for a physical or psychological disorder or syndrome? Yes No

If so, please name the medication _____

Are you pregnant? Yes No

Have you had or do you currently have any of the following?
(Please circle those which apply.)

Stroke Tuberculosis Epilepsy

Asthma Heart Condition Diabetes

Are you allergic to anything? Yes No

If so, what? _____

Do you ever get hives or rashes? Yes No

Is there anything else that you would like to bring to our attention? _____

Please indicate your physician's name and phone number below.

Name _____ Phone _____

People who are on medication for epilepsy or heart problems should get written medical consent from a physician. Pregnant women should not float. Those allergic to alcohol/solvents should not be fitted with electrodes. Those with rashes/sensitive skin should check reaction to tank solution before floating. People with contagious conditions can not float.

Before you take part in your first float, we would like to take this opportunity to explain a little bit about this study, as well as pass along a few pointers .

The flotation tank is a lightproof, sound-attenuated compartment. The water in which you will be floating is "heavy"; that is to say, it is saturated with epsom salts to increase a person's buoyancy. This water is also heated almost to body temperature. The combination of all these conditions often gives a floater the sensation of weightlessness.

The reactions to such an environment tend generally to reflect a pleasant state of relaxation, although floaters have experienced everything from euphoria to boredom. The relaxation response is easy to explain, for this is one of the few times in a person's life that every muscle is able to "let go".

There are a few tips that will make floating a little more satisfying for you. First, remember that the water you are floating in is very salty; try to avoid lifting your arms or performing any other move that might drip salt water in your eyes. Second, most people initially tend to hold their head up slightly; this puts a bit of strain on the neck muscles. The water will hold your head up, so relax your neck and allow your head to float gently. Finally, during the course of the float, one may find themselves "ping-ponging" very slowly from one side of the tank to the other. This is due mild currents set up by slight movements of the body; to stop it, simply spread your arms out and center yourself by touching both sides of the tank.

Thank you. We hope you enjoy your float.

Thank you for participating in our research. The purpose of this study is to examine how people's expectations affect the way in which their body responds to the environment. The expectations we were interested in have to do with the length of time a person believes he or she will be in an environment, as well as expectations regarding changes in environmental characteristics.

As part of our study, half of our subjects were told they would float for forty minutes; the other half were told they would float for eighty minutes. As well, some of our participants were told that changes in temperature, noise and light levels would occur towards the end of their float.

However, in order to study the effect of expectations alone, all participants floated in a constant, unchanging environment for sixty minutes. The mild deceptions regarding time and changes were the only way to alter the floater's beliefs about specific conditions.

We hope you have enjoyed the unique flotation experience. If you have any questions, the experimenter will be happy to answer them at this time.

Table I: Interval means for standardized T-wave amplitude by condition.

	Duration: 40 minute		80 minute	
	Environment: Similar	Dissimilar	Similar	Dissimilar
Interval 1	.374	.213	-.115	.107
2	.372	.297	.511	.486
3	-.194	.243	.121	.100
4	-.270	-.296	-.122	-.313
5	-.282	-.457	-.395	-.380

Table II: Interval means for standardized heart rate by condition.

Duration:	40 minute		80 minute	
Environment:	Similar	Dissimilar	Similar	Dissimilar
Interval 1	.428	.726	.614	.780
2	.044	.114	.199	.076
3	-.168	-.236	-.052	-.211
4	-.210	-.328	-.475	-.384
5	-.094	-.276	-.287	-.262

Table III: Grand means per interval for each dependent variable.

	Original		Transformed	
	Metric		Variables	
	TWA	HR	TWA	HR
	(μ v)	(bpm)		
Interval				
1	395	73.71	.145	.637
2	407	69.70	.417	.109
3	387	68.22	.068	-.167
4	368	67.96	-.250	-.349
5	359	67.86	-.378	-.251

Table IV: Results of multivariate tests

	Pillai	F	Hyp.	Err.	p <
			df	df	
Between Subject					
Duration	0.025	0.44	2	31	n.s.
Environment	0.104	1.81	2	31	n.s.
Duration x Environment	0.067	1.11	2	31	n.s.
Within Subject					
Intervals	0.823	14.54	8	25	.001
Duration x Intervals	0.243	1.00	8	25	n.s.
Environment x Intervals	0.162	0.60	8	25	n.s.
Duration x Environment					
x Intervals	0.156	0.58	8	25	n.s.

Table V: Single *df* polynomial contrasts for "Intervals" effect

Trend F(1,32) p <

TWA

Linear 31.556 .001

Quadratic 5.436 .05

Cubic 19.264 .001

Quartic 1.223 n.s.

HR

Linear 49.978 .001

Quadratic 29.663 .001

Cubic 0.057 n.s.

Quartic 1.808 n.s.

Figure 1: Hypothesized trends in arousal as influenced by durational and environmental similarity expectations.

Key

- 1 - Short duration and dissimilar environment
- 2 - Short duration and similar environment; or long duration and dissimilar environment
- 3 - Long duration and similar environment

Figure 2: Idealized cardiac waveform (after Furedy, 1987).

Figure 3: Telemetry system used for initial data acquisition and processing.

Figure 4: Equipment layout as used for digitization of analog EKG signal.

Figure 5: Plot of grand means of transformed TWA and HR variables by time interval.