A COMPARISON OF HEART RATE RECOVERY FROM PHYSICAL AND MENTAL STRESS

BY
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TABLE OF CONTENTS

LIST OF FIGURES

Abstract

The present study evaluated a new paradigm for identifying individuals who show exaggerated, delayed physiological recovery following mental stress. Subjects first performed a mental task, a face-to-face quiz, while heart rate was recorded. Ten minutes later they performed a physical task, squeezing a hand dynamometer, with the force varied in order to produce a heart rate elevation identical to the mental task. Each task was followed by a ten minute recovery period. Twenty seven subjects satisfied the criterion for equivalent heart rate elevations to both stressors.
A difference score, reflecting relatively slower recovery from the mental stressor (relative to the physical task), was significantly correlated with the Anger-Out subscale of the Anger Expression scale (Spielberger, Johnson, Russell, et al., 1985) for the first five minutes of recovery from the mental stressor. In contrast, residual recovery heart rate scores, controlling for resting and stress response level, were correlated with reported levels of physical fitness, but not personality factors. These results indicate the value of combining this new difference score paradigm with the standard residual score analysis of recovery to identify which factors are affecting recovery through psychological versus physiological mechanisms.

INTRODUCTION

There is increasing recognition that the stress experienced in today's society plays an important role in illness (Cox, 1978). Therefore, it is important to investigate the physiological consequences of stress which mediate this relationship. There has been considerable recent interest in the process of physiological recovery from stress (Hull, Young and Ziegler, 1984; Jamieson & Lavoie, 1987; Darr, Bassett, Morgan, & Thomas, 1988). It has been suggested that unnecessarily prolonged stress has negative health implications due to physical 'wear and tear' on the body (Dohrenwend & Dohrenwend, 1984). The purpose of the present study is to evaluate the potential of a new paradigm for identifying individuals who show exaggerated, delayed recovery responses.

Current definitions state that stress results when there is more of a demand on an individual than s/he is able to cope with (Lazarus, 1966). This imbalance of coping leads to the individual experiencing stress and its accompanying physiological response. The physiological response to stress reflects high levels of arousal in the autonomic nervous system and neuroendocrine system. The onset of stress activates the sympathetic branch of the autonomic nervous system to prepare the body for Cannon's 'fight or flight' reaction. Such preparation includes an increase in heart rate, constriction of blood vessels,

decrease of gastrointestinal activity, increased respiration rate, activation of sweat glands and dilation of pupils (Feist and Brannon, 1988).

While a variety of physiological and hormonal changes accompany the stress response, much recent interest has focused on cardiovascular responses. This emphasis has been due to the importance of coronary heart disease as a health problem in our society (Van Doornen & DeGeus, 1989).

There is a great deal of research examining cardiovascular responses to laboratory stressors (Manuck, Kasprowicz, Monroe, Larkin & Kaplan, 1989). The general procedure is to elicit stress (e.g. harassment, mental arithmetic, threat of shock) and record measures such as heart rate and blood pressure (Matthews, Weiss, Detre, Dembroski, Falkner, Manuck & Williams, 1986). Individuals exhibiting greater reactions can be identified and correlations of this greater reactivity studied. These correlates may be investigated to see if they correspond to traditional risk factors. Risk factors such as level of family hypertension and physical fitness have been found to correlate with reactivity (Krantz and Manuck, 1984; Holmes and Roth, 1985). Increased cardiovascular response to laboratory stressors has proven to be a valuable paradigm for investigating the physiological factors which may underly the stress-illness relationship.

Recovery from stress

While the magnitude of the response to stress has been widely studied, less attention has been directed towards the recovery phase of the stress response, i.e. how quickly the individual returns to normal physiological levels following the stress-induced arousal. Yet several recent authors have pointed out that the speed of recovery may be more important than the magnitude of the physiological response to stress. It is preferable to have rapid recovery from stressful events than either stress with prolonged recovery or no stress at all (Welford, 1974). Stress is a part of daily life and is necessary for optimal functioning and to improve one's coping abilities through experience. It would not be optimal to face a stressful situation without a physiological response; however a rapid physiological recovery following stress is desirable (Dillbeck & Orme-Johnson, 1987). A quick recovery is necessary because prolonged stress leads to exhaustion of an individual's coping resources and subsequently increases susceptibility to disease (Mandler, 1984).

Of increasing interest is the inability of some individuals to have an efficient cardiovascular recovery from stressful situations. The question now remains as to what factors would influence this slower rate of recovery.

Factors Affecting Recovery: Physical fitness

Physical fitness has been examined for its relationship to recovery from stress (Cox, Evans, & Jamieson, 1979; Sinyor, Schwartz, Peronnet, Brisson, & Seraganian, 1983; Hull, Young, & Ziegler, 1984; Holmes & Roth, 1985). Physical fitness is usually associated with an efficient physiologic response to physical work. The cardiovascular system becomes more efficient with physical fitness. Fit individuals have a larger stroke volume and subsequently their bodies are not in need of a faster heart rate. As a result, those who are physically fit have a lower baseline heart rate. It is established that fitness is related to faster cardiovascular recovery from physical stressors. A number of studies have found that an individual's level of physical fitness may in fact alter the speed of recovery from mental stress (Cox, Evans, & Jamieson, 1979; Sinyor, Schwartz, Peronnet, Brisson, & Seraganian, 1983; Hollander & Seraganian, 1984; Holmes, & Roth, 1985; Sinyor, Golden Steinert, & Seraganian, 1986). Conversely, other studies failed to detect an effect of physical fitness on recovery from mental stressors (Hull, Young, & Ziegler, 1984; Jamieson & Lavoie,1987).

Factors affecting recovery: Persisting cognitions

Though it is possible that faster recovery may be due to a more efficient cardiovascular system, another explanation for prolonged recovery from stress is the

involvement of a psychological component. If heart rate i slower to recover from psychological, but not physical, stressors, a psychological component may be identified as a factor influencing impaired cardiovascular recovery. One psychological component that has been identified as an influential factor in the recovery process is persisting cognitions. Sympathetic arousal may persist following stressor termination, mediated by cognitions elicited by the previous stress.

Horowitz (1975) examined the similarity between cognitions following traumatic stressors and laboratory stressors. He found a general tendency for stressful events to be followed by persisting cognitions in the form of intrusive and repetitive thought. The tendency to experience intrusive and repetitive thoughts after a stressful event was found to occur after mild and moderate stress events, not just major stresses, which result in the post traumatic stress syndrome.

Indirect evidence for the role of persisting cognitions was provided by Jamieson and Kaszor (1986). They found that a social comparison condition, in which subjects expected to receive feedback about their performance, was associated with delayed heart rate recovery from stress (Stroop Task).

Factors affecting recovery: Personality traits

Roger and Jamieson (1988) found that individuals scoring high on a measure of perseverative thinking

personality trait (Rehearsal scale, Roger & Nesshoever, 1987) exhibited slower heart rate recovery following a mental stressor. Another study also found that individuals who score high on the Rehearsal Scale had slower heart rate recovery patterns (Jamieson & Minthorn-Biggs, 1989).

Slower heart rate recovery from stressful tasks has also been found to correlate with measures of preferred mode of anger expression. Jamieson and Minthorn-Biggs (1989) found subjects scoring high on the Anger-In subscale of Spielberger's Anger Expression scale (Spielberger, Johnson, Russell, Crane, Jacobs, and Worden, 1985) exhibited delayed heart rate recovery.

Lai and Linden (1989) examined cardiovascular recovery using a design which manipulated the subject's opportunity to express aggression during the recovery period. Their findings were complex, involving interactions with gender and the opportunity to express aggression. Though not a main effect, the results of the subject's cardiovascular recovery patterns showed that males exhibiting Anger-Out had a faster cardiovascular recovery than Anger-In males. Conversely, the opposite relationship was found with females, where Anger-In females recovered faster than their counterparts.

Additional heart rate response to stress

Psychological stressors lead to cardiac adjustments that are over and above the body's required metabolic need. The difference between heart rate predicted from metabolic need and the recorded (actual) heart rate is termed 'additional heart rate'. The additional heart rate methodology takes into account the differences in the oxygen consumption demand of each task's response requirements (psychological and physical).

Turner and Carroll (1985) measured heart rate, oxygen consumption, and respiratory volume of 20 males during a video game, a mental arithmetic task and a graded exercise (bicycle). Heart rate was plotted against oxygen consumption for exercise and regression lines were calculated for each subject. Predicted heart rates were obtained from the regression lines and the oxygen consumptions during the video game and mental arithmetic task. The heart rates during both tasks were much higher than predicted for metabolic requirements, thus confirming the presence of additional heart rate.

A second study by Carroll, Turner and Hellawell (1986) confirmed earlier reports that heart rate during active psychological challenge is greater than the heart rate expected on the basis of HR/VO2 regressions during exercise. Stressors included a mental task and Raven's Matrices, each with three levels of difficulty, and a bicycle as a graded exercise. There was a computation of 'additional heart

rate' for each condition. As opposed to O2 and CO2, heart rate was seen to increase with difficulty of task. Subject's self-reports of arousal paralleled the cardiac effects.

Additional heart rate during recovery

In the preceding paradigm measuring additional heart rate during reactivity, a mouthpiece is required to collect expired gas in order to calculate the amount of oxygen used. This is cumbersome and limits exploration of other factors which may affect reactivity, eg. verbalization influences on heart rate (Brown, 1990).

The recovery period offers an alternative approach to defining the additional heart rate. It is not necessary to use oxygen consumption as a prediction measure to identify additional heart rate when the recovery period is examined. A comparison of the recovery periods from the physical and psychological stressors also serves as a method to identify extra heart rate.

Recovery is more difficult to study than the magnitude of response, since it is necessary to partial out both resting level and response magnitude in order to obtain an independent index of recovery. While more complex, the study of recovery offers a potentially valuable paradigm not available with response magnitude, namely the ability to match the magnitudes of response to different stressors. This matching enables one to obtain a 'difference score'

reflecting the relatively slower recovery from one type of stress. If two tasks (mental and physical) differ systematically, so that one reflects a large psychological component while the other reflects primarily a physical component, then the difference between measurements taken at identical times following each task will tend to reflect the relatively slower recovery from mental stress.

The present study

The following experiment is designed to compare heart rate recovery from physical stress and psychological stress. The psychological task to be used this experiment involves a moderately stressful face-to-face quiz and the physical stressor to be used is hand grip. If recovery is slower from psychological stress, then a difference score can be produced as an index of the delayed recovery.

Cognitions following the physical stressor will be minimized by using a non-threatening physical stressor and placing this stressor second in the experimental design. It is important to arrange the order of tasks with the mental stressor occurring first so that the subjects' reactivity to the physical stressor may be matched with their reactivity to the mental stressor. Also, the mental task will be presented first to minimize the psychological component of

anticipation which generally accompanies the first of a series of stressors (Manuck, Kasprowicz, Monroe, et al., 1989) Therefore, counterbalancing would not prove useful in this study.

The Roger and Nesshoever (1987) Rehearsal scale will be included to validate the difference score heart rate. The Rehearsal scale has been seen in previous studies to be related to cardiovascular recovery. Roger and Jamieson (1988) found that subjects scoring high on this measure of cognitive perseveration showed slower heart rate recovery. Two subscales of Spielberger's Anger Expression scale (Spielberger, Johnson, Russell, et al., 1985) will be included because of reports of slower cardiovascular recovery by subjects scoring high on the Anger-In scale (Jamieson & Minthorn-Biggs, 1989; Lai & Linden, 1989) and low on the Anger-Out scale (Lai & Linden, 1989). A measure of physical fitness will also be included because slower heart rate recovery has been reported for less fit individuals (Cox, Evans, & Jamieson, 1979).

METHOD

Subjects

Fifty one volunteers from introductory psychology courses participated in this study. The data from 27 subjects satisfied the criterion (described below) and made up the sample of the present study. This sample consisted of 16 females and 11 males aged 17-43 years (males: m=21 yrs; females: m=24 yrs.) The subjects were told the experiment involved a comparison of heart rate changes during a mental task and during mild physical activity. The selection process excluded students who were smokers and on medication which affects heart rate (eg. Ventalin). Subjects received one mark towards their grade in introductory psychology for participation.

Apparatus

Pre-experimental questionnaires were the 11-item Rehearsal Scale in true-false format (Roger and Nesshoever; 1987) and the 24-item Anger Expression Scale in 4 point Likert format (Spielberger, et al., 1985). The scores from the Anger Expression Scale provided two scores for each subject: anger directed inward (Anger-In), and anger directed outward (Anger-Out).

Heart rate was recorded by a photoplethysmographic transducer. The transducer was attached to a Beckman Type RS Polygraph and placed on the first phalanx of the left

hand middle finger. The polygraph was used in order to produce a hard copy of the subjects' heart rate for later analysis.

A pulse monitor (IBS model CT-4600B) was placed on the first phalanx of the subject's left hand first finger. Through the use of the pulse monitor the experimenter was able to watch the subjects' heart rate throughout the experiment.

The psychological stressor was presented in the form of a mental task. The mental task consisted of 60 prerecorded simple, common knowledge questions presented in a rapid fashion over a three minute time period (see Appendix 1).

The physical stressor was an isometric hand-grip exercise using a hand dynamometer (Lafayette, model 78010).

A post experimental questionnaire was given which asked the subjects how they felt during the experiment. Difficulty and level of commitment to the mental task, as well as the existence of the following five emotions: worry, confidence, anxiety, stress, and anger were assessed using four-point Likert scale formats. Questions also included the level of perceived physical fitness as compared to others of the same age, as well as gender and age (see Questionnaire in Appendix II).

Procedure

Upon arrival at the lab the subjects were asked to complete the pre-experimental questionnaires. After the questionnaires were completed the subjects were asked to be seated in a comfortable chair and the purpose of this experiment was partially explained as follows:

> There are two parts to this experiment. The first part involves mental activity and the second involves physical exertion. I'm studying heart rate and therefore need stable measures of your heart rate before, during and after each activity. When I say relax, just close your eyes and relax for a few minutes. I will explain more about the experiment later.

The two finger photoplethysmographs were attached to the subjects' first two fingers of the non-dominant hand, after which the following instructions were given:

> Please close your eyes and relax for ten minutes so that I can get your baseline heart rate.

After the ten minute rest period the subjects were asked to open their eyes and the mental stressor was presented. This task was three minutes in length. Before beginning, the subjects were told the following:

> I'm going to give you a quiz that consists of

> simple, common knowledge questions. The questions are presented very rapidly, please answer them as quickly and accurately as possible. When the quiz is finished I want you to remain in your seat and attempt to relax again. You will not be given your score on the quiz.

These instructions were designed to motivate the subjects to do well.

The experimenter feigned scoring throughout the quiz and demonstrated mild agitation with the subject's responses during the final 30 seconds of the quiz. This was done to encourage a rise in the subjects' heart rates as a result of increased motivation and challenge.

Following termination of the quiz the subjects were asked to close their eyes and rest for ten minutes.

After this rest period the subjects were instructed to open their eyes and were given the physical stressor. The subjects were initially asked to squeeze the dynamometer with their right hand as hard as they could. To provide a challenge the experimenter asked the subject to squeeze the handgrip 'to see how strong they were'. 40% of this maximum strength was calculated and the subjects were asked to squeeze the hand grip at this amount for three minutes. At this point the following instructions were given:

> I'm going to ask you to squeeze the handgrip

for three minutes, keeping the needle at _
I will tell you when to tighten and loosen
your grip. I'd like to remind you to keep
your other hand still in the process.
will tell you when to begin.

The experimenter asked the subjects to strengthen or lessen their grip with the goal of matching their heart rates for the physical task with the heart rates for the mental task. After the physical task the subjects were asked to rest for the final ten minutes.

A fixed order of task presentation was used in order to minimize the psychological component in the second (physical) stressor.

As the final step, the post-experimental questionnaire was presented to the subjects. Upon completion of this final questionnaire the subjects were debriefed (see Appendix III for outline).

The polygraph output was scored for heart rate by counting the number of beats that occurred during specific time intervals. The beats were counted during the last 30 seconds of the first rest period (baseline); the last 30 seconds of each stressor; the first two minutes of the two recovery periods from the stressors, broken into eight periods of 15 seconds; the last 30 seconds of the first recovery period (i.e. the second resting baseline); and each minute of the ten minute recovery periods.

Since the goal was to match subjects on their heart rates to the mental and physical stressors, only those subjects whose heart rates during the last 30 seconds of each stress period were within one beat were included for data analysis. This yielded a sample of 27 subjects. All heart rates were converted to beats per minute for purposes of analysis and illustration.

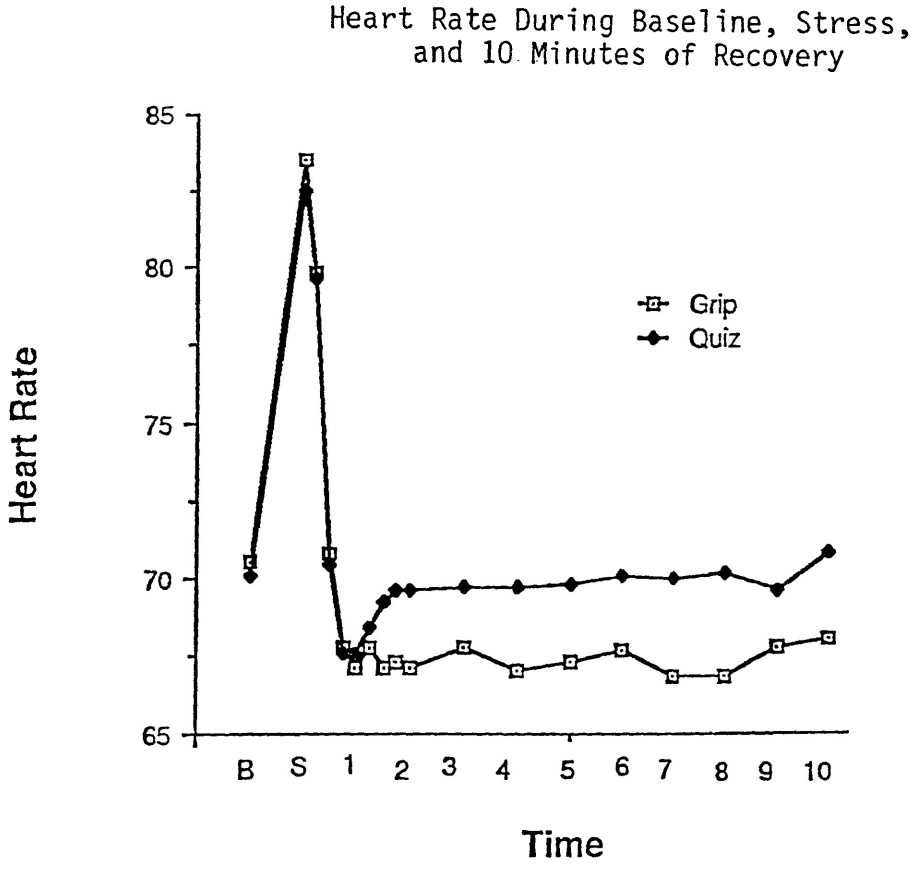
Results

The post-experimental questionnaire was included as a validity check concerning the stressfulness of the mental task. Ratings were on a four point scale (1=not at all, 2=somewhat, 3=moderately so, 4=very much so). Overall, the mental task was rated as somewhat easy, (m=2.333, std.dev.=.832). The subjects reported that they moderately cared whether or not they answered the questions correctly, (m=3.185, std.dev.=.921). The subjects also reported that they tried moderately hard to answer the questions correctly, (m=3.185, std.dev.=.834). In general, the subjects did not experience feelings of worry or anger during the mental task, (m=1.778, std.dev.=.698; m=1.296, std.dev.=.669 respectively). They were somewhat confident about the questions, (m=2.148, std.dev.=1.099), but felt moderately stressed (m=2.593, std.dev.=931).

Both the physical and mental stressors were effective in increasing heart rate; paired t-tests indicate the difference between baseline heart rates and stress heart rates to be significant (t's = 6.57, 7.46, p's < .001). Mean heart rates during baseline, the physical and mental stressors and each of the ten minutes of the recovery period are presented in Figure 1.

As seen in Figure 1, the two recovery curves are virtually identical until into the second minute when the recovery curve for the mental stressor exhibits an increase.

FIGURE 1

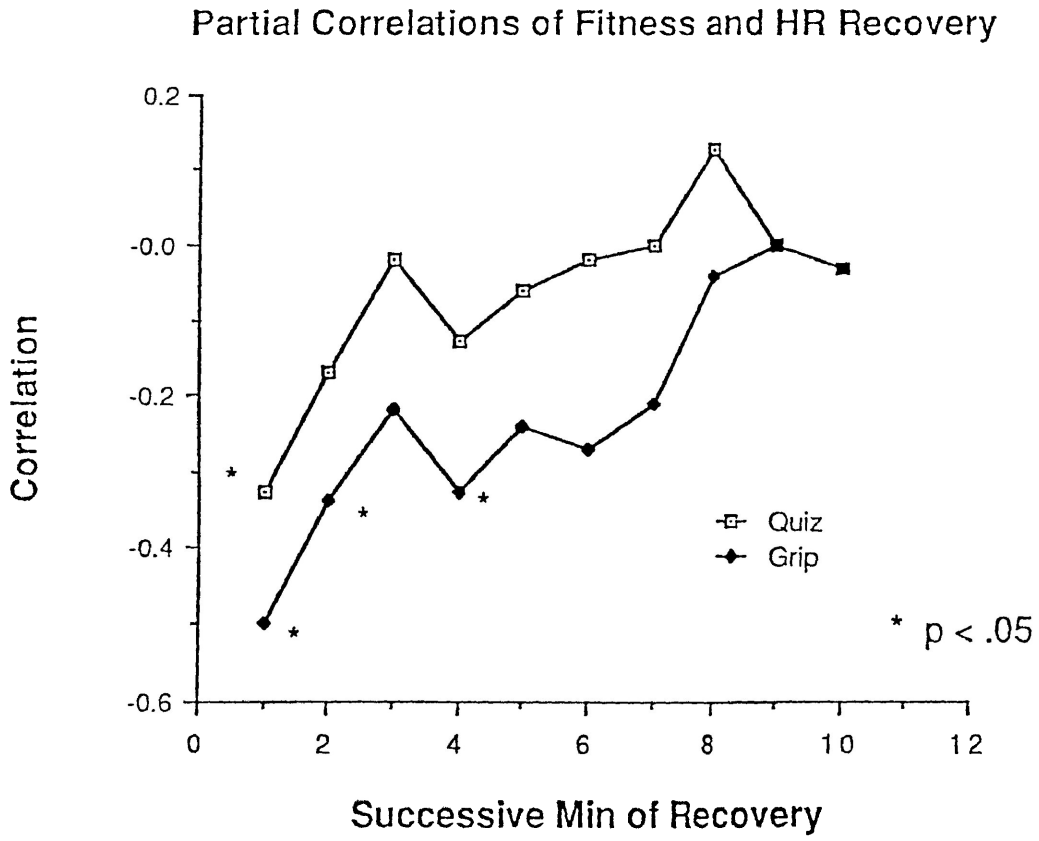

Heart Rate During Baseline, Stress,
and 10 Minutes of Recovery
Heart Rate
85
80
75
70
65
B
S
1
2
3
4
5
6
7
8
9
10
Time
Grip
Quiz

Referring back to Figure 1 shows that this increase is sustained throughout the ten minute recovery period.

To evaluate whether the physical and mental stressors produced different recovery patterns, paired t-tests were performed on heart rate for each of the ten minutes of the recovery period. These revealed a significantly higher heart rate during the second through tenth minute of recovery for the mental stressor than the physical stressor (Appendix IV).

To examine the relationship of various factors to heart rate recovery from each stressor, partial correlations were calculated. For this analysis resting heart rate and heart rate during the last 30 seconds of the stressor were controlled for. It is important to partial out these heart rates in order to examine recovery differences independent of baseline heart rate levels and independent of reactivity to the stressors. The factors of interest were: Rehearsal, Anger-In, Anger-Out, and rating of fitness level. Partial correlations were calculated for each of the ten minutes of recovery from each task. In general, the three personality scales did not correlate with recovery from either task (Appendix V). However, recovery from both tasks was significantly correlated with reported fitness level for the first minute following the mental task, and for the first, second and fourth minutes following the physical task. These partial correlations are plotted in Figure 2.

FIGURE 2

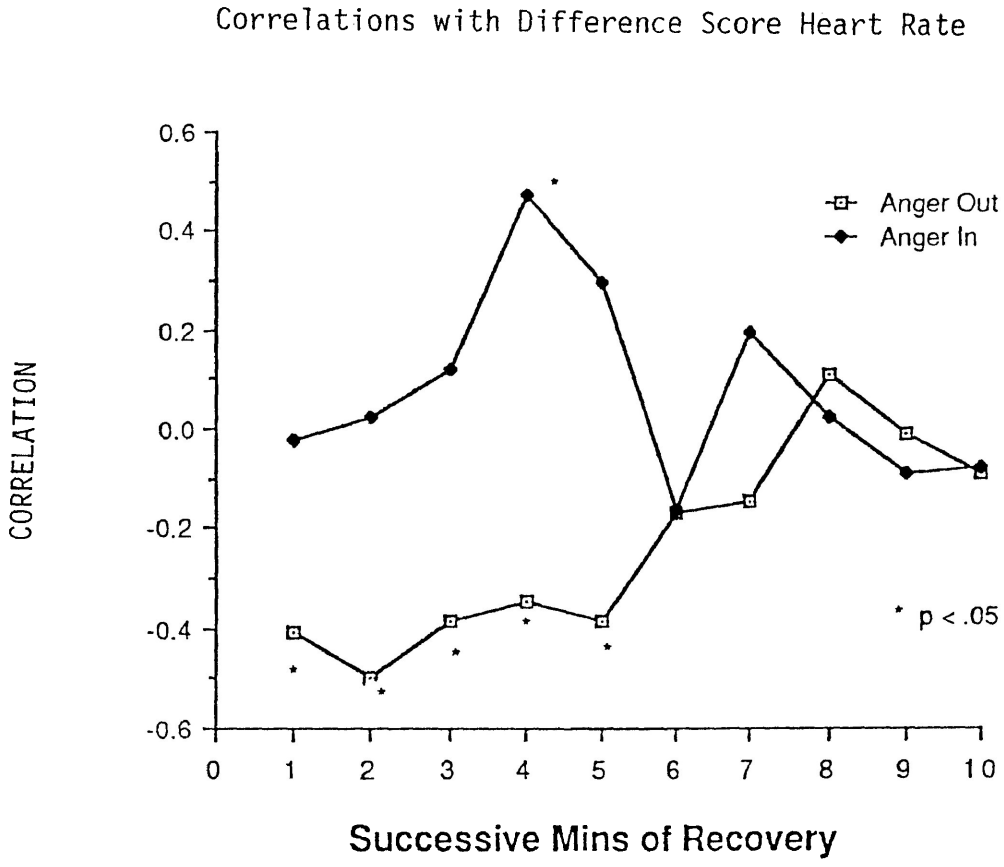

Partial Correlations of Fitness and HR Recovery
Correlation
0.2
-0.0
-0.2
-0.4
-0.6
0
2
4
6
8
10
12
Quiz
Grip
* p < .05
Successive Min of Recovery

One goal of the present study was to explore whether a difference score, reflecting relatively slower recovery from the mental stressor, would be a valuable index. Difference scores were calculated by subtracting heart rate during each minute of the physical stressor recovery period from the heart rates during the corresponding minute of the mental stressor recovery periods. Correlations between these scores and the four factors of interest were examined (Appendix VI). The difference score was significantly correlated with Anger-Out for each of the first five minutes of recovery. It was also correlated with Anger-In, but only during the fourth minute of recovery. These correlations are plotted in Figure 3.

Since Lai and Linden (1989) reported different results for male and females for Anger-In and Anger-Out, separate analyses were examined in the present study. Both the males and females peaked in their correlations at minute four. Correlations with Anger-In were as follows: males: $r(11) = 0.498$, $p = .06$; and females: $r(16) = 0.458$, $p = .037$. The two groups showed comparable large negative correlations with Anger-Out for the first five minutes of recovery, but not beyond, therefore, patterns of correlations for both these measures was virtually identical for both males and females.

Correlations were calculated for self-reports of affective and commitment responses to the mental stressor with heart rate recovery. Partial correlations with each

FIGURE 3


Correlations with Difference Score Heart Rate
CORRELATION
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0
1
2
3
4
5
6
7
8
9
10
Anger Out
Anger In
* p < .05
Successive Mins of Recovery

minute of the recovery period showed no consistent and significant results (Appendix VII). Similarily, correlations performed with difference scores and the self-report responses did not show a consistent pattern of significant results (Appendix VIII).

DISCUSSION

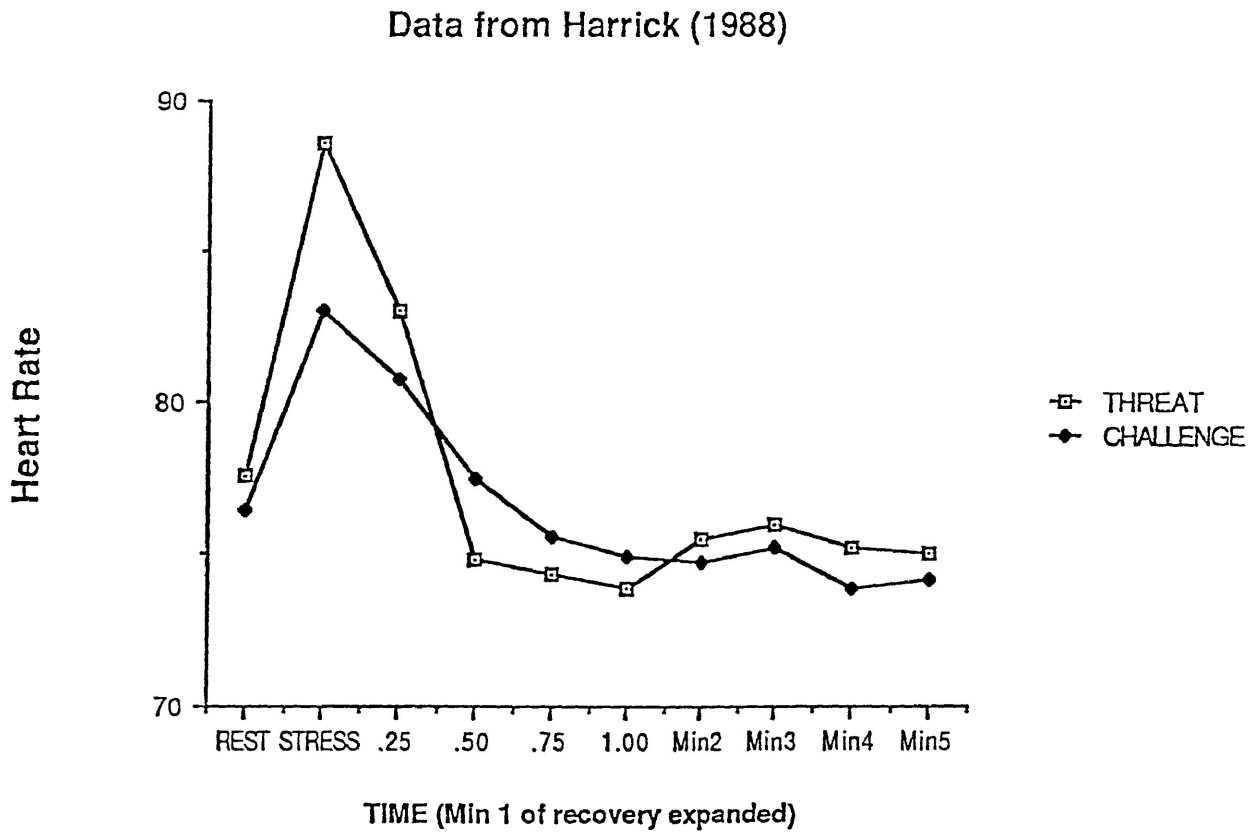
The new paradigm explored in this study appears feasible. It was possible to match the heart rates to within one beat in 30 seconds, for over half the subjects. Because the entire procedure required only one session, the rate of data loss is not a great expense, and suggests that this paradigm is of practical value. A number of findings emerged, and these will be addressed from two perspectives, first from a consideration of the mean heart rate recovery curves from both tasks, and second from an examination of the pattern of correlations with the difference heart rate and the residual heart rate scores.

Heart rate recovery curves

Both heart rate recovery curves exhibited virtually identical decreases to baseline levels within the first minute following each task. This lowered heart rate level was maintained following the physical stressor, but was followed by a return to a slightly higher level for the mental task.

This overshoot effect has also been apparent in other data sets (see Figure 4). In Harrick (1988) a mental stressor (Stroop task) was given under two different motivational instructions, designed to make the task either threatening or challenging. The overshoot was apparent in the threat condition, but not the challenge condition.

FIGURE 4


Data from Harrick (1988)
Heart Rate
90
80
70
REST STRESS .25 .50 .75 1.00 Min2 Min3 Min4 Min5
TIME (Min 1 of recovery expanded)
THREAT
CHALLENGE

This overshoot may reflect the influence of a psychological component. In this study the heart rate after the mental stressor decreased for the first 45 seconds of recovery and then increased slightly to a higher level after 1.5 minutes. The interesting aspect of this phenomena is not the decrease in heart rate, but the fact that the heart rate increases again. This pattern suggests an involvement of another component causing the heart rate to increase, i.e. a psychological component.

If attention is focused on the two conditions of Harrick's study, it is reasonable to expect a psychological component to follow the threat condition rather than the challenge condition. Such an overshoot phenomenon is apparent in Figure 4.

Correlates of heart rate recovery measures

Two indices of heart rate recovery were examined. The first was a residual score, representing heart rate at each minute of each recovery period with the preceding baseline and stress response heart rates partialled out. In this study residual scores only indicated significant correlations with the self report rating of physical fitness.

A simple question was included in the post-experimental questionnaire concerning fitness level rather than using a more rigorous method of assessment. While the simple self report measure of physical fitness used in this study is a

less satisfactory measure of fitness, there are studies supporting the validity of such self report indices (eg. Washburn, Adams, & Haile, 1987). This study does not provide data to validate this self-report measure of fitness, but the finding of slower recovery in less fit subjects is correlated in the same direction as reported in the literature.

The second index of recovery was the heart rate difference score. This was calculated for each minute of the recovery periods by subtracting the heart rate following the physical task from the heart rate following the mental task.

Figure 3 indicates that some correlations were found between this difference score and several personality scores. This difference score was significantly correlated with the Anger-Out subscale of the Anger Expression Scale for the first five minutes of recovery, with low Anger-Out subjects showing slower recovery from the mental stressor. The direction of this correlation is consistent with reports of hypertension being associated with suppression of anger (Dimsdale, Pierce, Schoenfeld, Brown, Zusman, & Graham, 1986). It is possible that the delayed cardiovascular recovery from mental stress exhibited by these individuals may play a role in the development of hypertension.

The difference score correlated with Anger-In, although the correlations were only significant at minute four. There were no significant correlations for the Rehearsal scale. Findings are not totally consistent with other

studies. As opposed to findings of Roger and Jamieson (1988) and Jamieson and Minthorn-Biggs (1989), this study did not find that individuals who score high on the Rehearsal Scale had slower heart rate recovery patterns or that Anger-In measures are predictive of delayed heart rate recovery as measured by residual scores. Failure to replicate these studies with a sample of 27 subjects is perhaps not too surprising because large sample sizes had been used in the previous studies and the correlations found were modest in magnitude.

It is also worth noting that the correlations between the heart rate difference scores and Anger-Out approached zero after five minutes of recovery (Figure 3), indicating that the effect tapped by the correlations was linked chronologically to the preceding stressor, and was not an effect which persisted throughout the 10 minute period. This finding suggests that the heart rate elevation following the mental task, relative to the physical task, does not reflect a single cause. It appears that low Anger-Out subjects experience elevated heart rate during the first five minutes of the mental task recovery period, presumably because of persisting emotional effects. However, the elevated heart rate for the remaining 5 minutes reflects a different process, likely anticipation of the next task.

While the present results indicate the potential

value of this difference score as an index of psychological processes occurring during recovery, it is also apparent that some factors affecting the rate of recovery are not detected by this measure.

In particular, the rating of fitness level was significantly correlated with the rate of recovery from both tasks, however this relationship largely disappeared when the difference score was examined. Thus, it appears that fitness affects an aspect of recovery which is common to both tasks. As well, the effect of fitness is not primarily on a psychological component, as measured by the extra heart rate difference score.

The difference score, which reflects relatively slower recovery from a mental stressor, appears to be more sensitive to personality factors, while the residual scores appear to be more sensitive to factors having a common influence on recovery from both mental and physical stressors, such as level of physical fitness.

The results of this study point to the value of combining this new difference score paradigm with standard residual score analyses of recovery in order to identify which factors affect recovery through psychological versus physiological mechanisms.

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APPENDIX I

Quiz used for the mental stressor.

1. 14 + 7
2. Who is the president of Chrysler?
3. 20 x 3
4. Do Deciduous trees lose their leaves?
5. Who is the premier of Ontario?
6. 9 + 23
7. How many days did it take God to create the earth?
8. What provincial capital is not a city?
9. 8 x 6
10. Who was the first man on the moon?
11. What is Canada's currency?
12. Where is Mt. Rushmore?
13. What is the largest country in South America?
14. Who deceived Jesus?
15. Who hosts the 'National'?
16. Who is the president of Lakehead University?
17. 26 + 11
18. What is the nation's capital?
19. Where are the provincial parliament buildings located?
20. 9 x 12
21. How many provinces are there in Eastern Canada?
22. What is the official language of Switzerland?
23. Where is New Zealand?

24. How many bones are in the human body?

25. What is the capital of France?

26. How many commandments are there?

27. Do you ever lie?

28. How many teeth in an adult mouth?

29. Who turned to salt in the Bible?

30. How many planets are there in the solar system?

31. What does the EEG measure?

32. What does the median refer to?

33. What is the capital of Manitoba?

34. What is Germany's currency?

35. What ocean is by Nova Scotia?

36. Who was the Prime Minister before Mulroney?

37. Who was the Prime Minister before Turner?

38. What was the name of the U.S. space shuttle that blew up?

39. What is Pierre Trudeau's middle name?

40. Who was the president before Regan?

41. How many legs do spiders have?

42. Who is the premier of British Columbia?

43. How many side does a hexagon have?

44. What is the 10th letter of the alphabet?

45. How was Goliath killed in the Bible?

46. Where is the Sahara Desert located?

47. Who is the Father of Psychology?

48. 18 x 3

49. 14 - 9

50. How old is Psychology?

51. Who is the leader of the federal N.D.P. party?

52. Who won the presidential election?

53. What is the capital of Iran?

54. How many states are there in the U.S.A.?

55. What is the population of Canada?

56. How many kilometres in a mile?

57. What is the largest river in the world?

58. What is the official language of Brazil?

59. 72 ÷ 8

60. What is 25^2?

Please answer the first four questions using the following scale:

1 = NOT AT ALL; 2 = SOMEWHAT; 3 = MODERATELY SO; 4 = VERY MUCH SO

1. How easy did you find the questions?

1 2 3

2. Did you care whether you answered the questions correctly?

1 2 3

3. Did you try hard to answer the questions correctly?

1 2 3 4

4. Please indicate the extent to which you felt each of the following emotions while answering the questions.

WORRIED	1	2	3	4
CONFIDENT	1	2	3	4
ANXIOUS	1	2	3	4
STRESSED	1	2	3	4
ANGRY	1	2	3	4

---

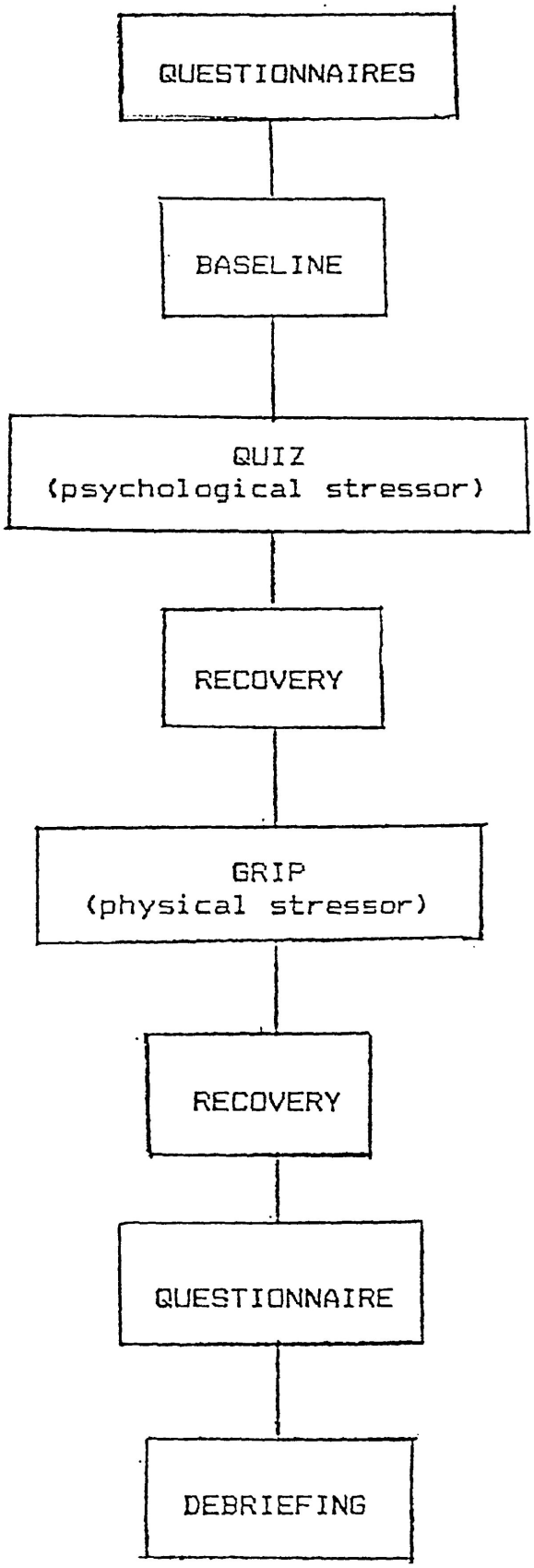
5. How physically fit do you feel you are, compared to the average student your age? (Circle one response)

MUCH LESS FIT ABOUT SAME MUCH MORE FIT

1 2 3 4 5

---

6. YOUR AGE _____ GENDER (male or female?) _____


QUESTIONNAIRES
BASELINE
QUIZ
(psychological stressor)
RECOVERY
GRIP
(physical stressor)
RECOVERY
QUESTIONNAIRE
DEBRIEFING

APPENDIX IV

Paired T-test on heart rate for each of the ten minutes of the recovery periods.

Variable	t value	2-tail prob.
Baseline	.44	.667
REC1	.04	.972
REC2	2.68	.013
REC3	2.30	.030
REC4	4.23	.000
REC5	3.31	.003
REC6	3.86	.001
REC7	3.38	.002
REC8	3.23	.003
REC9	2.25	.033
REC10	3.84	.001

Appendix V

Partial correlations of Anger-In, Anger-Out, Rehearsal and fitness level with heart rate during each of the ten minutes of recovery from the mental stressor.

	Anger-In	Anger-Out	Rehearsal	Fitness
QR1	-.0617	-.2239	.1298	* -.3353
QR2	-.1096	-.1900	.3023	-.1766
QR3	-.0375	-.1685	.1930	-.0296
QR4	.0728	-.1350	.2727	-.1321
QR5	.2350	-.1868	.1388	-.0678
QR6	-.1140	-.0118	.2012	-.0272
QR7	.1964	.0887	.0167	-.0041
QR8	.2457	* .3588	-.1418	.1310
QR9	.1502	.1797	.0638	.0071
QR10	.1338	.0934	.1549	-.0316

* $p < .05$

...appendix V cont'd...

Partial correlations of Anger-In, Anger-Out, Rehearsal, and Fitness level with heart rate during each of the ten minutes of recovery from the physical stressor.

	Anger-In	Anger-Out	Rehearsal	Fitness
GR1	-.0761	-.0546	-.0106	* -.5001
GR2	-.1879	-.0402	.0048	* -.3428
GR3	-.2002	.0208	.1191	-.2245
GR4	-.2881	-.0484	.1085	* -.3342
GR5	-.1213	.0342	.1462	-.2452
GR6	-.0221	-.0531	.1216	-.2778
GR7	-.1545	-.1011	.1891	-.2199
GR8	.2088	-.1140	.1738	-.0433
GR9	.2694	-.1132	-.1063	-.0005
GR10	* .3579	-.1446	-.0319	-.0338

* $p < .05$

Appendix VI

Correlations of difference scores with Anger-In, Anger-Out, Rehearsal and Fitness Level

	ANGER-IN	ANGER-OUT	REHEARSAL	FITNESS
DR1	-.0177	-.4076	.0431	-.2969
DR2	.0202	-.4957	.2452	-.3384
DR3	.1246	-.3825	.0162	-.0346
DR4	* .4675	-.3483	.0365	-.0671
DR5	.2927	-.3830	-.1031	-.0630
DR6	-.1621	-.1671	.0512	.0395
DR7	.1952	-.1467	-.2137	-.2266
DR8	.0212	.1132	-.3301	-.1285
DR9	-.0990	-.0096	.0572	-.2255
DR10	-.0803	-.0916	.1184	-.3040

* $p < .05$

APPENDIX VII

Partial correlations of self-report measures with heart rate during each of the ten minutes of recovery from the mental stressor.

	EASY	COMMITMENT	EFFORT	WORRY
QR1	.1364	-.2280	.0188	-.3020
QR2	.2443	-.2010	-.0171	-.2575
QR3	.3298	-.1042	.1020	-.0623
QR4	.1012	-.2758	.0169	-.3401
QR5	.2504	-.0635	.0809	-.0850
QR6	.2167	-.1423	.0421	-.2129
QR7	.3475	-.3638	-.1675	-.0667
QR8	.0585	-.2144	-.2045	.1669
QR9	.1380	-.2988	.0396	-.0816
QR10	.2523	* -.4426	-.1023	-.0620

* $p < .05$ (two-tailed)

..appendix VII cont'd...

	CONFIDENT	ANXIOUS	STRESSED	ANGRY
QR1	-.1218	-.2348	-.1549	.3967
QR2	-.0134	-.0988	-.2601	.0761
QR3	.0573	-.1360	-.2074	.0623
QR4	-.0448	-.1366	-.3454	.0687
QR5	.1592	.1594	-.3128	.0840
QR6	.1238	-.0835	-.3887	-.0119
QR7	.0952	.0192	-.3045	.1014
QR8	-.0063	.2313	-.1440	.1407
QR9	.1531	.0949	-.2062	-.0185
QR10	-.0265	.0900	-.1234	-.0662

* p < .05 (two-tailed)

Partial correlations of self-report measures with heart rate during each the ten minutes of recovery from the physical stressor.

	EASY	COMMITMENT	EFFORT	WORRY
GR1	-.2905	-.1394	.0786	-.2481
GR2	.0008	-.0977	.0729	-.3402
GR3	-.0538	-.0878	.1709	-.4109
GR4	-.1941	-.0427	.1272	-.2450
GR5	-.0272	-.1713	.1070	-.2813
GR6	-.0678	-.1252	.0920	-.1866
GR7	-.1810	.0525	.2042	-.4756
GR8	.2118	-.1325	.2279	-.3327
GR9	.1880	-.1587	.0527	-.1947
GR10	.3054	-.0950	.1862	-.2893

* p < .05 (two-tailed)

	CONFIDENT	ANXIOUS	STRESSED	ANGRY
GR1	-.0931	-.0374	-.1057	.0951
GR2	.1905	-.2220	* -.4342	.0329
GR3	.2173	-.0842	* -.4994	-.0095
GR4	.0895	-.0217	-.3678	.2468
GR5	.0013	-.0565	-.2645	-.0218
GR6	.1022	.0473	-.3004	.1866
GR7	.2126	-.3095	* -.5443	.1200
GR8	.1626	-.2324	-.3259	.0264
GR9	.1560	-.1607	-.1132	-.0832
GR10	.2355	-.3066	* -.4053	-.0805

*p < .05 (two-tailed)

Appendix VIII

Correlations of difference scores with self-report responses.

	EASY	COMMITMENT	EFFORT	WORRY
DR1	* .3815	.2104	.0477	.0580
DR2	.1886	.1926	.0928	.1031
DR3	.3249	.2353	.0600	.2690
DR4	.2172	-.0025	-.0302	.0727
DR5	.1084	.3075	.0935	.1818
DR6	.1841	.2705	.1740	-.1580
DR7	.3316	-.0262	-.1315	.2988
DR8	-.1671	.1791	-.1887	.3411
DR9	-.1207	.1363	.1639	.0628
DR10	-.1041	-.2157	-.1571	.2608

* $p < .05$ (two-tailed)

	CONFIDENT	ANXIOUS	STRESSED	ANGRY
DR1	.0774	-.0320	.2565	.1811
DR2	-.1150	.1900	.3546	.0443
DR3	-.0251	-.1234	.3367	.0457
DR4	-.1087	-.0892	.1490	-.2291
DR5	.1889	.0909	.0042	.0591
DR6	.2249	-.2391	-.1888	-.2505
DR7	-.0098	.2327	.3587	-.0323
DR8	-.0136	.2748	.1855	.0688
DR9	.1345	.1476	-.0394	.0145
DR10	-.1858	.3390	.2332	-.0194

* p < .05 (two-tailed)