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Int J Psychophysiol. Author manuscript; available in PMC 2011 July 7.

Published in final edited form as:
Int J Psychophysiol. 2010 July ; 77(1): 35–42. doi:10.1016/j.ijpsycho.2010.04.004.

Appraisal predicts hemodynamic reactivity in a naturalistic stressor

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Abstract

Prior research has shown that appraisals are predictive of hemodynamic reaction patterns. The current study examined the relationship between appraisal and hemodynamic responding in a real-life stressful situation. Twenty-four men aged 19–28 wore a blood pressure monitor while presenting a paper in a class.

Participant's appraisal self-reports were obtained prior to the stressor. Multilevel regression models were used to analyze the relationships between appraisal and myocardial responding (as measured by cardiac output) and vascular resistance (as measured by TPR).

Pre-stressor appraisals were significantly associated with CO, both during the stressor (Z=2.03 p<.05) as well as during the 30-minute anticipation period preceding the stressor (Z=2.43 p<.01). In line with the predictions, relatively challenged participants showed higher CO. Pre-stressor appraisals significantly predicted TPR during anticipation (Z=2.70 p<.01) but these associations failed to reach significance during the stressor (Z =1.82, n.s.). As was predicted, during anticipation, increased threat was associated with increased TPR. Thus, during the anticipation period prior to the stressor, increased challenge was associated with decreased vascular resistance and increased myocardial reactivity. Further, increased threat was associated with increased vascular resistance and decreased myocardial reactivity. During the stressor increases in challenge were associated with further increases in myocardial responding but relationships between appraisal and vascular resistance were not significant.

The current study shows that the relationship between appraisal and hemodynamic reactivity seen in laboratory studies are also present during naturally occurring stress. Our findings suggest that threat appraisals to naturalistic stressors contribute to an, arguably unhealthy, vascular reaction pattern.

Keywords

Ambulatory; Hemodynamic; Appraisal; Portapres; Naturalistic; Stress; Cardiac output; Total peripheral resistance

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1. Introduction

It is widely held that the cardiovascular response to psychological stress is a risk factor for cardiovascular disease, the reactivity hypothesis (Krantz & Manuck, 1984). Cardiovascular reactivity is usually assessed by measuring the CV response to laboratory stressors. The assumption underlying the use of laboratory stressors is that the responses seen in the laboratory are typical of those that occur in everyday life such that individuals who show a large response to laboratory stressors also show larger or more frequent responses in everyday life. While rarely made explicit it is also assumed that the processes underpinning cardiovascular reactivity are similar in laboratory and field settings. There has been extensive research on the generalisation of the CV reactivity from laboratory to field and while results are mixed (Kamarck & Lovallo, 2003; Linden et al., 2003, Schwartz et al., 2003) there is some evidence of generalisation to both specific naturalistic stressors and self reported stress in everyday life (Johnston et al., 2008). However there have been few attempts to determine if the psychophysiological processes determining CV reactivity to naturalistic stressors are the same as those established by laboratory studies.

Blood pressure reactivity is determined by two hemodynamic parameters; the output of the heart (Cardiac Output [CO]) and vascular resistance (Total Peripheral Resistance [TPR]) (Berne & Levy, 1997; Guyton & Hall, 2000). Hemodynamic response patterns differ among individuals and these characteristics appear to be relatively stable. Thus, individuals may be labelled as myocardial, vascular or mixed responders (Kasprowicz et al., 1990; Sherwood & Turner, 1995). A vascular reaction pattern may contribute to structural adaptations of the heart and the vasculature. Short-term vascular responsiveness may promote vascular hypertrophy due to recurring stimulation of vascular muscle (Sherwood & Turner, 1995). Furthermore, stress-induced vascular responsiveness has been shown to predict left ventricular hypertrophy (Sherwood & Turner, 1995). Steptoe and Marmot (Steptoe & Marmot, 2005) found that vascular responsiveness was predictive of increased BP 3 years later. Ottaviani et al. (Ottaviani et al., 2007) recently found evidence suggesting a link between a vascular recovery pattern and inflammatory cardiovascular risk factors.

Hemodynamic reactivity patterns are affected by a person's reaction to a stressor, which is in turn related to the perception or appraisal of the stressor. Differential hemodynamic response patterns are elicited in reaction to active and passive coping. Active coping with a stressful situation is associated with a myocardial response (Obrist, 1981). In contrast, passive coping is associated with a vascular response pattern (Sherwood et al., 1986; Brownley et al., 2000).

More recently, Tomaka and colleagues (Tomaka et al., 1993; Tomaka et al., 1997) showed that appraisals are predictive of hemodynamic reaction patterns. Challenge and threat appraisal were predictive of myocardial and vascular reactivity, respectively. The concepts of challenge and threat appraisal stem from the work of Lazarus and Folkman (Lazarus, 1966; Lazarus & Folkman, 1984). Blascovich and Tomaka (1996) operationalise appraisal as the outcome of a comparison of perceived situational demands and perceived resources. Challenge appraisals result when resources are perceived to be sufficient or nearly sufficient in comparison to perceived demands. A threat appraisal is made when perceived resources are considered insufficient to meet the demands (Blascovich and Mendes, 2000). Correlational studies provided evidence suggesting that during active coping tasks, challenged individuals showed a myocardial response whereas threatened individuals showed a vascular response (Tomaka et al., 1993; Heffner et al., 2002, Quigley et al., 2002). In addition, experimental manipulations of stressor appraisal provided further evidence for the hypothesised links between appraisal and hemodynamic responding. In these studies, challenge and threat appraisals were manipulated by using challenging or threatening task

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instructions or situational characteristics (Tomaka et al., 1997; Blascovich et al., 1999; Blascovich et al., 2001; Mendes et al., 2002; Weisbuch-Remington et al., 2005).

Research on hemodynamic reaction patterns in relation to appraisal has been carried out in the laboratory, using a limited range of mental stress tests. Relatively recently, non-invasive ambulatory equipment has been developed that allows the study of hemodynamic reaction patterns in everyday life situations. Nevertheless, to date, we are not aware of any research that has been carried out on the hemodynamic response to everyday life stress and relating this to appraisal.

The current aim is to test whether the relationships between appraisal and hemodynamic responding observed in the laboratory are found in everyday life stressful situations. It is examined whether the appraisal-related hemodynamic differences can be found, even in the face of uncontrollable nuisance variables that are characteristic of naturalistic settings.

In the current study, participants' hemodynamic reactivity was measured before, during and after performance of a speech, a task used successfully to study the generalisation of the magnitude of CV responses from laboratory to field (Johnston et al., 2008). Giving a speech is an active coping task that can be characterised as a motivated performance situation that is goal-relevant (i.e. having real or imagined consequences). Public speaking is a task that has a social-evaluative component, and self-presentation concerns make such a task highly goal-relevant. Accordingly, it may be argued that task involvement will be uniformly high for all participants. These characteristics make the current stressor suitable to test the hypothesized relationships between appraisal and hemodynamic reactivity.

It is hypothesised that, during the stressor, challenged participants will show a myocardial response, whereas threatened participants are hypothesised to show a vascular response.

Anticipation of the stressor is more difficult to characterise, as it may involve both active and passive components. It may be argued that that the anticipation phase is a (relatively) passive stressor since active coping with the stressor (public speaking) is impossible before the start of this stressor. At the same time, stressor anticipation may involve active coping such as rehearsal of the talk.

Finally, it is hypothesised that, during recovery, cardiovascular arousal levels will return to baseline levels. In the current conceptual framework no predictions are specified for the relationship between appraisal and changes in hemodynamic parameters.

2. Methods

2.1. Participants

Participants were twenty-six males. Gender appears to moderate the relationship between physiology, appraisal and behaviour (Quigley et al., 2002). To avoid this complication in a study with a small sample the current study did not include female participants. Participant recruitment took place via the distribution of e-mails and posters in the University of Aberdeen. Cardiovascular data in two participants was lost due to equipment failure. The final sample of participants therefore numbered twenty-four. For this final sample, participants' ages ranged 19–28 (mean age: 23.5; SD: 2.5). Participants' BMI ranged from 17.4 to 34.7 (mean BMI: 23.7; SD: 4.4). Two participants had a BMI higher than 30. Participants were non-smokers, and they were asked to avoid drinking coffee during the day of testing. None of the participants used medication. Three participants reported use of alcohol in the past 24 h, but the highest number of alcohol units reported was no more than

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2. The study was granted approval by the University of Aberdeen, School of Psychology Ethics Committee. Each participant gave informed consent and received 12 GBP.

2.2. Self-report measures

2.2.1. Appraisal—Challenge and threat appraisal was conceptualised as the outcome of a comparison between perceived demands and perceived resources. If a participant perceives the situation as a threat then perceived demands outweigh resources. If the participant perceives the situation as a challenge then perceived resources outweigh perceived demands. In order to measure situational appraisal, demand and resource ratings were combined into a ratio, by dividing demands by resources. An appraisal ratio larger than 1 indicates ‘threat’ whereas an appraisal ratio smaller than 1 indicates ‘challenge’ (Tomaka et al., 1993; Blascovich & Tomaka, 1996; Tomaka et al., 1997).

Following Tomaka et al, (Tomaka et al., 1993; Tomaka et al., 1997) in the current study, ratings on single-item measures of perceptions of demands and perceptions of resources were combined into a ratio. Ratings were given on a 7-point Likert scale. In the current study, perceived demands were measured using the item ‘How demanding do you think the presentation will be?’ Perceived resources were measured using the item ‘How able are you to cope with this presentation’.

In order to assess whether the presentation was stressful (manipulation check), participants’ self-reports were obtained using the item ‘How stressful do you expect the presentation to be’.

2.3. Equipment

2.3.1. Portapres—Continuous, non-invasive finger arterial pressure was recorded with a Portapres Model-2 at a sampling rate of 100 Hz. Portapres is the portable version of Finapres. Portapres consists of a belt, which holds a pump, a memory card, as well as a hydrostatic pressure measurement device, which records the position of the hand. The vertical distance between hand and heart may change from time to time, due to hand movements. Therefore, height correction of the blood pressure signal needs to be carried out in order to control for artifactual effects of hand position on the finger pressure.

Portapres uses two finger cuffs, rather than one (cf. Finapres). An automatic finger switching system was set to switch between index and middle finger every 30min to avoid discomfort and venous congestion.

Portapres has been shown to provide reliable and accurate BP readings (Imholz et al., 1993; Hirschl et al., 1999). The blood pressure waveform-derived hemodynamic measures are considered indices of SV, CO and TPR rather than measures of these parameters. Calibration is necessary in order to obtain accurate absolute measures of hemodynamic parameters (Voogel & Van Montfrans, 1997). However, as in our case, if the focus is on the measurement of changes in hemodynamic parameters over time, then calibration is not necessary as Modelflow-derived hemodynamic reactivity parameters can be tracked with the same precision as comparison measures (e.g. thermodilution) (Van Lieshout & Karemaker, 2003).

2.4. Data analysis

2.4.1. Data reduction—In the current study, the following cardiovascular variables were measured: BP (systolic, mean and diastolic); heart rate, SV, CO and TPR.

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HR values were derived from the BP waveform. Beatfast software was used to analyse the raw BP waveform in order to derive systolic, diastolic, and mean BP as well as CO, SV and TPR. Modelflow analysis (embedded in the Beatfast software) derives beat-to-beat values for SV, TPR and CO (Modelflow software; TNO, Amsterdam, The Netherlands).

Before importing the data into the statistical analysis software, periods of interest were identified and selected from the datasets. The 30-minute period before the start of the stressor was labelled the anticipation phase. The duration of the stressor differed per participant and ranged between 5 and 49min (mean duration: 21min, SE: 12min). The 30-minute period following the stressor was labelled the recovery phase.

2.5. Artifact correction

After obtaining the beat-to-beat values for the cardiovascular variables (SBP, MBP, DBP, CO, HR, TPR and SV), these data were subsequently imported into Carspan (Mulder, 1980). Artifact detection and correction was carried out by means of the Carspan software: moving averages were calculated for time windows of 60 seconds. A value was identified as an artifact if it exceeds a confidence interval of +/−4 SDs around that moving average. Artifact correction involved replacing the artifact with a value obtained by linear interpolation between two preceding and two successive values.

After initial artifact correction, the data were summarised into one-minute means. The one-minute means for each variable were then imported into the statistical analysis software. Here, the data were visually inspected for artifacts both collapsed over participants as well as within participants. Data points that were identified as artifacts were extreme outliers that were physiologically improbable. These, less than 3% of the data, were deleted and replaced by missing value codes.

2.6. Procedure

The study involved a field measurement of cardiovascular activity, before, during and after a presentation. Ambulatory cardiovascular measures were recorded before (anticipation phase), during (stressor phase) and after (recovery phase) performance of a presentation as part of the individual’s course requirements (in students) or job.

Participants responded by email to recruitment posters and emails that were sent out to the student body. In response to the participants’ email, they were provided with further information about the study.

Participants were required to come to the lab at two occasions; at least 2h before and at least 1h after they had given their presentation.

After obtaining participants’ written consent, the participant’s height and weight were measured. Manual blood pressure measures were taken, using a non-invasive semiautomatic osscillometric sphygmanometer (Takeda UA 751, Takeda Medical, Tokyo, Japan). Next, the participant was connected to the Portapres. After connecting and setting up the Portapres, participants were asked to fill out a form inquiring after age, smoking, alcohol use and medication use. Furthermore, participants were asked to fill out the appraisal self-report.

Subsequently, participants were sent away and given a paper and pencil appraisal questionnaire (see below) to take with them. Furthermore, participants were asked to press an event marker at the start and at the end of their presentations.

The experimenter encouraged the participants to give their presentation in the second half of the (typically) hour-long tutorial, 18 out of 24 did so. Duration of the presentation (stressor)

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ranged between 5 and 49min (mean: 20.8min (SD: 12.4). Self-reported audience size during the participants' presentations ranged from 4 to 60 (mean: 17.7; SD: 12.9). Ten of the participants reported receiving a mark for their presentation; thirteen participants did not receive a mark. Fifteen participants stood during their presentations; while eight participants sat during their presentations. For one participant this data was missing.

During the second and final laboratory session, the participant returned to have the Portapres disconnected and to fill out some final questionnaires. After the Portapres was disconnected and after having filled out the questionnaires, the participants were debriefed, reimbursed thanked and dismissed.

2.7. Analytic models

The current data were analysed using multilevel regression models. Multilevel modelling has several advantages over more traditional statistical approaches such as repeated measures ANOVA and OLS regression. Like repeated measures ANOVA multilevel regression models take account of the clustering of measurements within groups, however multilevel regression models are not restricted to balanced designs. Also multilevel models use random effects to model the between individual variation, rather than the fixed effects used in repeated measures ANOVA, this allows a greater generality of inference beyond the sample. Furthermore multilevel models allow the inclusion of higher level covariates which is not possible in repeated measures ANOVA (Hox, 1998; Quigley et al., 2002; Rasbash et al., 2004).

In the first set of models, within-subjects changes in CV arousal levels are modelled. These models examined changes in CV arousal over the three phases (anticipation–stressor–recovery), contrasting each phase with the other two phases.

The second set of statistical models addressed the relationships between appraisal and hemodynamic reactivity (CO & TPR). These were two-level models: at level 1, within-subjects changes in hemodynamic reactivity over time (in minutes) were modelled. At level 2, between-subjects differences in participants are modelled. Outcome variables were CVR during anticipation, during the stressor and during recovery. The main predictor was appraisal, along with the relevant control variables. Anticipation, stressor and recovery readings are analysed separately.

Appraisal as a predictor of CVR was modelled as a between-subjects variable.

The relationship between appraisal and CVR was controlled for the between-subjects variables BMI (Body Mass Index) and self-reports of; age, audience size, whether participants sat or stood during the stressor and whether the presentation was marked or not and finally the number of alcohol units ingested in the past 24h. For the prediction of CVR during anticipation and recovery, 'stand or sit' was not a predictor as during these phases, posture was not known.

Data analysis was carried out using MLwiN 2.02, a software package designed for carrying out multilevel regression analysis. Unstandardized Beta estimates were calculated for all models specified (see below).

Multilevel modelling uses a maximum likelihood estimation procedure to model the relationships between predictor and outcome variables. The current data is modelled using the Restricted Iterative Generalised Least Squares (RIGLS) algorithm.

In order to overcome problems associated with autocorrelation we attempted to simultaneously model the multilevel and autocorrelation structures using a method described

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in Goldstein, Healy and Rasbash (Goldstein et al., 1994). However, these models did not converge. Therefore, robust estimators for the standard errors of the fixed predictors are reported in order to protect against downward bias in the standard errors. Robust estimators for the standard errors provide more accurate significance tests and confidence intervals in case of non-normality than the ordinary (‘asymptotic’) residuals (Hox, 2002).

Hypothesis testing may be carried out by constructing 95% confidence intervals for the beta estimates, in order to test whether the predictors are significantly related to the outcome variables. In multilevel modelling, typically a *Z*-test (or Wald test) is used (Hox, 2002).

3. Results

3.1. Self-reported stressfulness

As was described above, prior to stressor exposure, participants were asked ‘How stressful do you expect the presentation to be’ on a scale ranging from 1 (not at all) to 7 (extremely). Post stressor ratings were obtained by the question ‘How stressful was the presentation? The mean of the stressfulness ratings was 4.08 (95% C.I.: 3.50–4.67). Post-stressor ratings of perceived stressfulness had a mean of 3.2 (95% C.I.: 2.87–3.53). These ratings suggest that the stressor was perceived as moderately stressful. The stressfulness ratings were significantly (positively) correlated with the appraisal ratio (r=.65, p<.001).

3.2. Cardiovascular arousal levels before, during and after the stressor

Figs. 1 and 2 show the changes in HR and MBP over time for the anticipation, stressor and recovery phases. For each phase the means for the tertiles of total phase duration are displayed in order to accommodate the differences in stressor duration between participants.

In order to evaluate cardiovascular arousal levels during the stressor, these were contrasted with CV arousal levels during anticipation and recovery. Furthermore, anticipation CV levels were compared to those obtained during recovery.

Analyses showed that the BP variables (SBP, MBP and DBP), as well as TPR significantly increased from anticipation to stress. On the other hand, SV decreased from anticipation to stressor. The BP variables, as well as CO and HR all decreased from stressor to recovery. Changes in CVR as a function of recovery compared to stressor were nonsignificant in SV and TPR (see Table 1.1). In comparison to recovery, anticipation levels of SBP, HR and CO were significantly elevated while TPR was significantly higher during recovery (see Table 1.2).

3.3. Appraisal and hemodynamic responding

The mean of the pre-stressor appraisal ratios self reports was 0.79, with a range of 0.14–1.25. Since the average appraisal ratio is smaller than 1, on average, ratings for perceived resources were higher than those for perceived demands.

3.3.1. Anticipation—During anticipation, appraisal significantly predicted changes in TPR and CO. The relationship between appraisal and TPR was positive; an increase in the appraisal ratio predicted increases in TPR. Thus, relatively threatened participants showed increased TPR during anticipation. The relationship between appraisal and CO was negative; participants who were relatively challenged showed an increase in CO (see Table 2.1).

3.3.2. Stressor—During the stressor, appraisal significantly predicted changes in CO, such that relatively challenged individuals showed increased CO (see Table 2.2).

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3.3.3. Recovery—During recovery, no significant associations were found between pre-stressor appraisal and CO or TPR (see Table 2.3).

4. Discussion

The current study examined the relationship between appraisal and hemodynamic responding in a naturalistic stressful situation. Speaking in public was associated with substantial increases in CV activity. As predicted, during anticipation of the stressor, increased challenge was associated with decreased vascular resistance and increased myocardial reactivity. Similarly, during anticipation of speaking, increased threat was associated with increased vascular resistance and decreased myocardial reactivity. Furthermore, during the stressor increases in challenge were associated with increases in myocardial responding although the relationships with TPR were not reliable.

What does this study add to the existing literature? The current study extends the work by Tomaka and colleagues (Tomaka et al., 1993; Tomaka et al., 1997) in several ways. Most importantly, it was shown that it is feasible to study hemodynamic reaction patterns in a naturalistic stressor and relate these patterns to situational and individual variables. It is important to establish that these associations exist in real life in order to address the question if appraisal-related changes in vascular reactivity may contribute to an unhealthy hemodynamic profile.

Furthermore, the current study involved the measurement of hemodynamic changes over time, while previous studies used a much more static approach, analysing rest-task differences. The use of repeated measures of the cardiovascular variables provides a richer picture of the cardiovascular response to this naturalistic stressor and its association with appraisal. In addition, using more data points results in enhanced reliability of the cardiovascular measures. Furthermore the stressors used in this study were of different durations and were of (much) longer duration than the stressors employed in Tomaka et al. (1993; 1997), showing that the effects obtained are relatively independent of stressor duration and generalise to stressors of longer duration.

The multilevel regression models used to analyse the data are a more defensible statistical approach than the ANOVAs and regression models used in prior research. In addition, rather than using a dichotomous variable indicating challenge or threat, the current study used a continuous variable.

The results of this study support the hypotheses as the expected response patterns were obtained. Appraisal was found to predict the hemodynamic variables CO and TPR as hypothesised. Further, as hypothesised, appraisal did not predict any of the other five cardiovascular variables that were measured. Thus, in this study appraisal was shown to have specificity in the prediction of cardiovascular parameters. Furthermore, in prior research, relationships between appraisal and hemodynamic profile were typically examined in tasks that lasted no longer than 5 min. The stressors were of variable length, ranging between 5 and 50min.

The stressor employed in the current study was a public speaking stressor. In laboratory studies, speech tasks have been shown to be a realistic, relatively ecologically valid laboratory task. The results of studies on hemodynamic response patterns elicited by the speech task are inconsistent (Hurwitz et al., 1993; AlAbsi et al., 1997; Llabre et al., 1998). The speech stressor appears to be able to elicit both types of responses: vascular and myocardial, and is therefore a useful task to test individual differences in hemodynamic responding. No clear pattern in situational hemodynamic reactivity emerges, perhaps due to

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variations in the speech tasks employed in different studies, or due to individual differences in appraisal.

In the current study, available data on postural changes and activity levels is limited to self-report. In an earlier study of ambulatory BP reactivity, activity, muscle activity and posture were measured objectively (Jain et al., 1998). Clearly this is preferable particularly in the analyses of HR which is very metabolically driven. In the current study, participants were asked whether they sat or stood during their presentation and this information was used as a covariate. There is no a priori reason to assume that posture or activity are associated with stressor appraisal, such that posture and activity would be a confounding factor in the association between appraisal and hemodynamic reactivity. Rather, since the effects of posture and activity were imperfectly measured it is probable that allowing for these effects will weaken rather than artifactually strengthen our findings. In future research, statistically controlling for objectively measured activity and posture may enhance the statistical associations between appraisal and hemodynamic reactivity. A further limitation is sample size. Difficulties with participant recruitment resulted in a relatively small sample (24 participants). Despite this, reliable relationships between stress hemodynamic measures and appraisal were demonstrated.

Future research, in addition to the inclusion of the aforementioned behavioural data (posture, activity), may also benefit from repeatedly measured stressor appraisals, as well as the inclusion of other relevant self-reports, to better characterise the psychological processes that are associated with vascular and myocardial response patterns as a function of time.

A number of other features of the study are worthy of comment. Self-reports of perceived stressfulness did suggest that the stressor was moderately stressful. In the work by Tomaka et al. (1993, 1997) the baseline period typically involved measuring cardiovascular variables during the last minute before the start of the task. Baseline and task measures were combined into a single difference score for each cardiovascular variable (cf. Tomaka et al., 1993, Tomaka et al., 1997). In the current study, the mean cardiovascular arousal levels were higher during the stressor than during the 30 min preceding the stressor (anticipation) for BP and TPR but not CO and its determinants HR, SV (see Table 1.1). The myocardium is very responsive and parameters such as HR, CO and SV tend to rise and fall very rapidly. It is likely that arousal levels in these myocardial variables were already elevated during anticipation and therefore started to drop once the participant had been speaking for a few minutes. HR and CO were markedly higher during anticipation than recovery.

Baseline measures may be taken outside the laboratory and on the same day, during a period which can be demonstrated to be non-stressful (Johnston et al., 2008). In Johnston et al. (2008) the baseline period did not necessarily precede the stressor period. In the current study, it may be argued that rather than the period that precedes the stressor, the period that follows the stressor could serve as a baseline comparison. In comparison to the recovery phase, BP levels as well as HR and CO were higher during stressor. This suggests that the stressor was indeed sufficiently stressful to engender the expected increases in cardiovascular arousal.

As can be seen in Table 1.1, SBP showed an increase of 21.5 mmHg during stressor in comparison to recovery. This constitutes an increase of 15% over the mean of 143.8 during baseline (recovery). HR was 12.5 bpm higher during the stressor than during the recovery phase. Similarly, this increase constitutes a 15% increase over the mean of 84.1 during baseline (recovery). These values during the stressor are very similar to those reported by Turner et al. (1990) in a similar study involving ambulatory measurement of cardiovascular reactivity during a realistic speech stressor. However, baseline levels in Turner et al. (1990)

are much lower than we find. Davig, Larkin and Goodie (2000) and Kamarck, Debski and Manuck (2000) report cardiovascular arousal levels for baseline and stressor periods that were similar to the values reported in Turner et al. (Turner et al., 1990). Altogether, the above suggests that for the current data, cardiovascular arousal levels obtained during the stressor replicate findings obtained in prior research using ambulatory equipment in discrete naturalistic stressors. However, baseline levels in Turner et al. (1990), Kamarck et al. (2000) and Davig et al. (2000) are much lower than the baseline (recovery) levels obtained in the current study. During recovery, cardiovascular arousal levels may still be elevated. Therefore, the use of recovery measures as a baseline may provide conservative estimates of the cardiovascular stress response during stressor exposure in the current study.

In summary, BP and HR levels during the stressor in the current study were similar to those obtained in prior studies, which involved the measurement of cardiovascular responding during a naturalistic stressor, even though different methods were used for the measurement of BP. In addition, cardiovascular arousal levels during stressor were generally higher than those obtained during a recovery baseline. This suggests that the stressor was indeed stressful.

Since the stressor is an active coping task, the general hemodynamic reaction pattern can be expected to be cardiac: characterised by increases in CO and decreases in TPR. Indeed, in comparison to the recovery phase, HR and CO were higher during the stressor, suggesting a myocardial response (see Table 1.1). TPR did not differ between the recovery and stressor phases.

In the current approach, it is assumed that within the constraints of the model (i.e. in situations that are goal-relevant and metabolically undemanding; see Blascovich & Tomaka (1996)), the relationships between threat and hemodynamic reactivity mirror the relationships between challenge and hemodynamic reactivity. In other words: within these constraints, challenge and threat can be operationalised as a single dimension, for the prediction of hemodynamic reactivity. Folkman and Lazarus (1985) have shown that participants report both challenge and threat appraisals at the same time: these appraisals are not mutually exclusive. Folkman and Lazarus designed a study to assess emotion, appraisal and coping strategy in students, before, during and after an examination. Threat and challenge self-reports were not correlated in this study (Folkman & Lazarus, 1985). Future research may compare two-dimensional and single-dimensional operationalisations of the challenge and threat constructs in the prediction of hemodynamic reactivity.

Finally, the use of self-report measures of demand and resource appraisal may be regarded as a limitation as these appraisals are by definition not necessarily available to conscious awareness (Lazarus & Folkman, 1984). Furthermore, it has been argued that men may be less likely to report being threatened, due to a reporting bias (Quigley et al., 2002). Other methods used to measure appraisals include observation e.g. Kline, Saab, & Llabre (2005) obtained observer ratings of nervousness as an index of ‘perceived’ demands. ‘Perceived’ resources were measured by observations of task performance, as the latter may be seen as a proxy for coping ability (Kline et al., 2005). However, this study did not find the expected associations between the ratio of demands and resources and hemodynamic response patterns, which arguably may be related to the observational nature of the appraisal measures. Experimental studies manipulating challenge and threat have been successful in obtaining group-differences in vascular and myocardial response patterns. In these studies, appraisals were manipulated by giving participants challenge or threat instructions, or by asking participants to cooperate with a stigmatized or otherwise devalued confederate (Blascovich et al., 1999; Blascovich et al., 2001; Mendes et al., 2002; Tomaka et al., 1997). Finally, Weisbuch-Remington et al. (2005) used a priming paradigm to affect subconscious

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appraisals and showed that participants in the challenge and threat did differ in hemodynamic responding to a subsequent stressor. These studies used different operationalizations of the appraisal constructs that may better measure subconscious aspects of appraisal than the self-reports used in the current study.

Finally, if challenge and threat responses are indeed respectively adaptive and maladaptive reaction patterns, as suggested by Dienstbier (1989), then changing appraisal from threat to challenge may be beneficial in the prevention of future cardiovascular disease. Short-term vascular responsiveness may contribute to disease by promoting vascular hypertrophy due to recurring stimulation of vascular muscle. Furthermore, stress-induced vascular responsiveness has been shown to predict left ventricular hypertrophy (Sherwood & Turner, 1995). Thus, the short-term increases in vascular resistance that were found in the current study may contribute to structural adaptations of the heart and the vasculature. In order for the current research to inform future interventions that enhance challenge and or reduce threat, it should involve the induction of longer-term changes in cognitive appraisal tendencies.

The current study examined the hemodynamic response patterns in association with challenge and threat appraisal in a naturalistic, stressful situation. Current findings provide initial evidence that the relationship between appraisal and hemodynamic reactivity seen in laboratory studies are also present during naturally occurring stress. Our findings suggest that threat appraisals to naturalistic stressors contribute to an, arguably unhealthy, vascular reaction pattern.

Abbreviations

ANOVA	analysis of variance
CO	cardiac output
CV	cardiovascular
CVR	cardiovascular reactivity
DBP	diastolic blood pressure
MBP	mean blood pressure
OLS	ordinary least squares
SBP	systolic blood pressure
SV	stroke volume
TPR	total peripheral resistance

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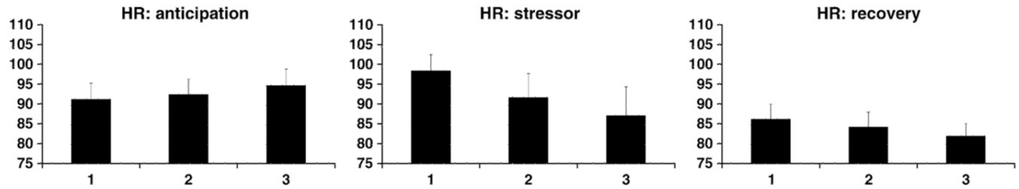

Fig. 1.
HR during the first, second and third tertile of the duration of the anticipation, stressor and recovery phases, error bars represent the standard error of the mean.

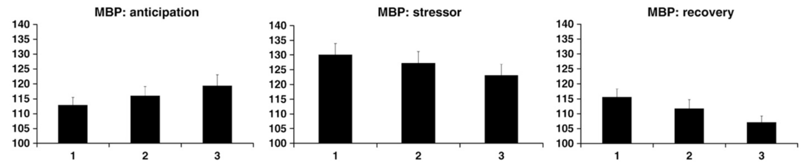

Fig. 2.
MBP during the first, second and third tertile of the duration of the anticipation, stressor and recovery phases, error bars represent the standard error of the mean.

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Table 1.1

Regression estimates in the prediction of cardiovascular responding during anticipation, stressor and recovery from phase. The β_1 and β_2 estimates represent the contrasts between stressor and recovery levels and recovery and stressor levels, respectively.

Variable	β_0 constant	SE β_0	β_1 anticipation v. stressor	SE β_1	β_2 recovery v. stressor	SE β_2	Variance Components			
							Person level Intercept (σ^2_{u0})	SE	Phase level Intercept (σ^2_e)	SE
Systolic Blood Pressure	165.23*	4.57	−13.04*	4.19	−21.48*	3.81	235.84	69.16	291.71	9.56
Diastolic Blood Pressure	102.91*	2.79	−8.75*	2.37	−11.62*	2.48	90.56	26.52	101.51	3.33
Mean Blood Pressure	126.70*	3.36	−10.57*	3.04	−15.23*	2.93	123.16	36.14	157.49	5.16
Heart Rate	96.52*	4.22	−3.64	2.31	−12.47*	2.35	320.08	92.74	107.82	3.49
Cardiac Output	7.19*	0.39	0.31	0.21	−0.62*	0.20	2.61	0.76	1.44	0.05
Stroke Volume	76.66*	3.65	6.27*	1.92	2.83	2.37	244.51	71.05	128.95	4.2
Total Peripheral Resistance	1135.76*	63.98	−137.72*	41.38	−50.81	49.61	50146.32	14652.65	49662.13	1613.3

Note. All beta estimates are unstandardized. Robust SE's are reported.

Phase (anticipation, stressor, and recovery) is dummy-coded.

For the anticipation dummy variable: anticipation is coded as 1 and both stress and recovery are coded as 0. Similarly, for the recovery dummy variable: recovery is coded as 1 and both anticipation and stress are coded as 0.

* $p<.0$.

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Table 1.2

Regression estimates in the prediction of cardiovascular responding during anticipation, stressor and recovery from phase. The β_1 estimate represents the contrasts between anticipation and recovery levels. The β_2 estimate that was used to contrast stressor and recovery periods is not reported in this table, as it is already displayed in Table 2.1 a.

Variable	β_0 constant	SE β_0	β_1 anticipation v. recovery	SE β_1	Variance Components			
					Person level Intercept (σ^2_{u0})	SE	level Intercept (σ^2_e)	SE
Systolic Blood Pressure	143.75*	3.18	8.44*	3.39	235.84	69.16	291.71	9.56
Diastolic Blood Pressure	91.29*	2.02	2.87	2.00	90.56	26.52	101.51	3.33
Mean Blood Pressure	111.47*	2.38	4.66	2.51	123.16	36.14	157.49	5.16
Heart Rate	84.05*	3.46	8.83*	1.90	320.08	92.74	107.82	3.49
Cardiac Output	6.58*	0.30	0.93*	0.14	2.61	0.76	1.44	0.05
Stroke Volume	79.49*	2.99	3.44	1.93	244.515	71.05	128.96	4.2
Total Peripheral Resistance	1084.94*	45.38	−86.91*	42.72	50,146.18	14,652.73	49,662.12	1613.28

Note. All beta estimates are unstandardized. Robust SE’s are reported.

Phase (anticipation, stressor, and recovery) is dummy-coded.

For the anticipation dummy variable: anticipation is coded as 1 and both stress and recovery are coded as 0. Similarly, for the stress dummy variable: stress is coded as 1 and both anticipation and recovery are coded as 0.

* $p<.0$.

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Table 2.1

Regression estimates in the prediction of cardiovascular responding from appraisal ratio during anticipation.

Variable	β_0 constant	SE β_0	β_1 appraisal ratio	SE β_1	Variance Components			
					Person level Intercept (σ^2_{u0})	SE	Minute level Intercept (σ^2_e)	SE
Cardiac Output	−3.22	2.96	−1.39*	0.57	1.02	0.32	1.38	0.08
Total Peripheral Resistance	2776.61*	492.86	243.24*	90.0	28,210.04	8588.37	29,473.94	1628.78

Note. All beta estimates are unstandardized. Robust SE's are reported.

Not reported here but included in the analyses are the control variables; BMI, age, audience size, whether the presentation is marked or not and number of alcohol units ingested in the past 24 h.

* $p < .05$.

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Table 2.2

Regression estimates in the prediction of cardiovascular responding from the appraisal ratio during the stressor.

Variable	β_0 constant	SE β_0	β_1 appraisal ratio	SE β_1	Variance Components			
					Person level Intercept (σ^2_{u0})	SE	Minute level Intercept (σ^2_e)	SE
Cardiac Output	−1.97	3.21	−2.06*	1.01	1.97	0.6	0.74	0.05
Total Peripheral Resistance	3184.77*	556.94	345.73	189.72	61,844.8	18,831.85	31,344.52	2062.34

Note. All beta estimates are unstandardized. Robust SE's are reported.

Not reported here but included in the analyses are the control variables; BMI, age, audience size, posture (whether participants sat or stood), whether the presentation is marked or not and number of alcohol units ingested in the past 24h.

* $p<.05$.

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Table 2.3

Regression estimates in the prediction of cardiovascular responding from the appraisal ratio during recovery.

Variable	β_0 constant	SE β_0	β_1 appraisal ratio	SE β_1	Variance Components			
					Person level Intercept (σ^2_{u0})	SE	Minute level Intercept (σ^2_e)	SE
Cardiac Output	−0.22	3.06	−1.47	0.81	1.15	0.35	1.01	0.06
Total Peripheral Resistance	2223.23*	624.83	241.54	168.86	41,163.65	12,431.69	29,838.92	1633.94

Note. All beta estimates are unstandardized. Robust SE's are reported.

Not reported here but included in the analyses are the control variables; BMI, age, audience size, whether the presentation is marked or not and number of alcohol units ingested in the past 24h.

* p<.05.