

Positive affect and biological function in everyday life

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Abstract

There is accumulating evidence that positive affect may protect against ill-health and risk of disease. Here, we summarize results from our research program into the biological correlates of positive affect. Data have been collected from middle-aged men and women, with positive affect assessed through repeated ratings of happiness over a working day. The results indicate that greater happiness is associated with lower salivary cortisol both on working and nonworking days, reduced fibrinogen stress responses, and lower ambulatory heart rate in men. These effects are independent of age, socioeconomic status, smoking, body mass and psychological distress. A 3 year follow-up has confirmed these biological associations with happiness. In addition, we found that happiness was inversely related to ambulatory systolic blood pressure on follow-up, again independently of potential confounders including negative affect. These results suggest that positive affective states are linked to favorable health outcomes through their influence on health-related biology, and may be particularly relevant in old age, when the accumulation of risk factors leads to increased risk of chronic disease.

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1. Introduction

There is compelling evidence that negative affective traits, such as depression and anxiety are associated with adverse health outcomes. Longitudinal observational studies have established relationships with cardiovascular disease risk, diabetes, progression of disability, and premature mortality [9,15]. A notion that is being increasingly studied is the converse possibility that positive well-being and affect have favorable effects, reducing the rate of premature mortality and the development of various physical illnesses [2,7]. Such effects may be particularly relevant to older sectors of the population, among whom aging processes and the accumulation of risk factors lead to a high incidence of chronic disease. The maintenance of positive well-being with advancing years may help protect against in age-related morbidity.

If positive affect is associated with good health, the question arises as to which pathways underlie this relation-

ship. This question has led to research into the biological correlates of positive affect. Some studies have indicated that positive affect is associated with characteristic patterns of electrocortical activation [16], although findings are not entirely consistent [17]. Positive mood in everyday life also appears to be associated with high levels of central serotonergic function [1], a potentially important relationship in view of the links between deficient serotonergic function and higher body mass index (BMI), insulin resistance and blood pressure [5]. Neuroendocrine and immune responses have also been examined as possible mediators of the health effects of positive affect with some positive results [7].

Since positive and negative affect are inversely correlated, the demonstration that positive states are associated with reduced biological responses may be trivial, merely reflecting the absence of negative affect [7]. The conclusions that can be drawn from studies that have measured the biological correlates of positive affect without controlling for negative states are therefore ambiguous. We recently reported an investigation of late middle-aged men and women in which positive affect was associated with lower cortisol, lower heart rate,

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and reduced fibrinogen stress responsivity [13]. These effects were independent of known confounders, such as age and socioeconomic position, and also of negative mood states as indexed by the General Health Questionnaire (GHQ). In this article, we provide a summary of these findings, then present new data demonstrating the stability of the biological correlates of positive affect over a 3 year period.

2. Biological function in everyday life

Several methods are used to study biological factors in relation to psychological variables, such as positive affect, including laboratory experiments and epidemiological surveys. A particularly attractive strategy is measurement of biological function under naturalistic conditions, since it overcomes some of the limitations of other methods. The criticism is often made of laboratory studies that the situation is unrepresentative of real life, and that the acute responses observed experimentally are not relevant to chronic biological dysfunctions. Epidemiological approaches seldom involve measurement of biological activity on more than a single occasion, and this may be unsatisfactory for indicators that fluctuate over time. The measurement of biological function in everyday life using ambulatory, noninvasive methods allows the relationship between natural variations in physiological activity and psychological state to be assessed.

The biological variables that have been studied most intensively are ambulatory blood pressure and heart rate and salivary cortisol concentration. Repeated measures in everyday life are especially appropriate for these biological indicators, since all show marked variation over the day. They are also highly relevant to long-term health risk. Dysregulation of cortisol is implicated in a range of disorders, including depression, abdominal adiposity, type 2 diabetes, hypertension and inflammatory conditions, while raised blood pressure and heart rate are risk factors for coronary heart disease.

There are two different methods of analyzing the relationship between psychological factors and biological function everyday life. The first is the within-subject method, in which covariation between psychological states and biological variations are assessed. Such methods have generated some evidence that cortisol levels are lower when people are in more positive mood states [11], but have also shown that blood pressure is often higher in positive than neutral mood states [10]. The second method involves between-subject analysis, comparing individuals who differ in the psychological factor under investigation. This method has been used less frequently for studying positive affect, and previous findings have been inconsistent. Polk et al. [6] studied 334 men and women with cortisol sampled several times over the day and evening. Positive affect was derived from ratings obtained daily for 14 days. Higher levels of positive affect were associated with lower cortisol levels, with effects being larger in women than men. Volunteers took part in this study immediately before an investigation involving experimental infection

with the common cold, and were quarantined in a hotel over the measurement period, so the conditions of assessment were atypical. In contrast, no relationship was observed between positive affect and cortisol sampled from saliva in another study of women aged 61 and older [8].

3. Whitehall psychobiology study

The analyses that we have carried out were part of the Whitehall psychobiology study, an investigation of the biological processes associated with psychosocial risk factors for coronary heart disease [12]. This study involved monitoring of biological function in everyday life and measurement of responses to mental stress testing in the laboratory in a subgroup of the larger Whitehall II epidemiological cohort. A major focus was on socioeconomic disparities in health, and the greater cardiovascular disease risk in lower socioeconomic status (SES) individuals. Because of this, we recruited participants systematically across grades of employment, to allow us to compare higher, intermediate and lower SES groups. Ambulatory monitoring of blood pressure and heart rate using a Spacelabs 90217 device was carried out by 227 men and women over a working day and evening. The monitor was programmed to take a reading every 20 min from morning until bed-time. Additionally, eight saliva samples were taken at 2 h intervals over the same day, starting at 8.00–8.30, and finishing at 22.00–22.30. Saliva samples were also obtained over a weekend leisure day using this schedule, and data were analyzed by immunoassay at the University of Düsseldorf.

We hypothesized that positive affect would be associated with lower cortisol levels over the working and leisure day, and with lower ambulatory blood pressure and heart rate. We also reasoned that if the association between positive affect and biology was independent of negative affect, then it would persist after controlling statistically for psychological distress, as indexed by the GHQ.

3.1. Measurement of positive affect

Most work on affective states relies on global estimates of positive and negative affect, taken with ratings or questionnaires on a single occasion. Such methods have been criticized on the grounds that single measures are strongly affected by current state, memory distortion and recall bias [14]. Even though the respondent may be asked about mood over the past week or month, he or she is likely to be strongly influenced by mood over the past few minutes. It has been argued that a more reliable method is to assess momentary experience repeatedly on several occasions. This technique takes account of fluctuations in mood, and aggregates of momentary measures may provide robust estimates of typical levels of positive affect. In our study, participants gave ratings of happiness on a five-point scale (from 1 = *low* to 5 = *high*) after every blood pressure reading. We obtained an

average of 33 happiness ratings over the working day, and averaged these to generate an estimate of usual level of positive affect.

4. Cross-sectional findings

The study involved men and women aged 47–59 years. All were of white European origin, living within the London area, and with no history of coronary heart disease or hypertension. Satisfactory happiness ratings were provided by 216 of the 227 participants (116 men and 100 women). The remainder either did not carry out ambulatory monitoring for the complete day and evening, or did not fill in the accompanying diary. We computed the proportion of happiness ratings for each person that were positive (score of 4 or 5) on the working day, and this ranged from 0% to 100%. Participants were divided into quintiles of happiness in the main analysis; however, the same pattern of results emerged when happiness was analyzed as a continuous variable.

The proportion of positive happiness ratings averaged $1.2 \pm 2.0\%$, $16.7 \pm 6.9\%$, $40.9 \pm 8.9\%$, $80.6 \pm 12.6\%$, and $99.1 \pm 1.4\%$ in the five quintiles. Interestingly, this pattern did not vary between men and women. Happiness ratings on the work day were highly correlated with ratings on the leisure day ($r = 0.65$, $p < 0.001$), and were negatively associated with GHQ scores. Positive affect defined on the basis of mood over the working day therefore generalized to a leisure day, and happier people experienced lower psychological distress.

Cortisol showed the expected diurnal variation, being high in the morning and declining over the day. Mean cortisol was inversely associated with happiness quintile after adjustment for age, grade of employment, smoking status, BMI and GHQ score ($p = 0.009$). Cortisol averaged 6.43 ± 1.9 nmol/L in the highest quintile, and 8.49 ± 2.8 nmol/L in the lowest happiness quintile, a 32% difference. This finding is illustrated in Fig. 1, where the individual data points across the day

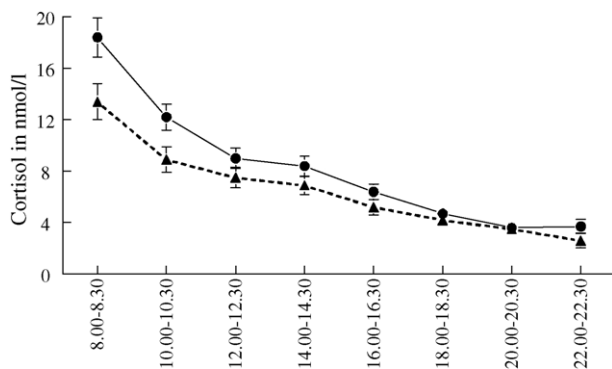


Fig. 1. Mean salivary cortisol sampled at 2 h intervals over the working day in participants in the lowest (solid line) and highest (dashed line) happiness quintiles. Values are adjusted for age, gender, grade of employment, smoking, body mass index, and GHQ scores. Error bars are standard error of the mean (S.E.M.).

are plotted for the highest and lowest happiness quintiles. The differences between participants are more prominent early in the day, though the group by sample time interaction was not significant. Happiness was also associated with cortisol on the leisure day, after adjusting for the same covariates ($p = 0.026$). Again, the highest average levels were recorded in the least happy quintile (8.24 ± 14.1 nmol/L), with the lowest cortisol being found in the happiest participants (mean 6.17 ± 1.8 nmol/L). These results were consistent with our primary hypothesis, and indicate that positive affect is inversely associated with cortisol in everyday life [13].

No association was observed between positive affect and blood pressure. In the case of heart rate, a significant effect was present in men but not women. Among men, greater happiness was associated with lower heart rates over the working day after adjustment for age, grade of employment, smoking, BMI, concurrent physical activity level and GHQ scores ($p = 0.033$). The difference between the highest and lowest happiness quintiles averaged 4.65 bpm, after adjusting for covariates.

Other differences in biological response related to happiness were recorded during laboratory mental stress testing. Specifically, happier individuals showed markedly smaller fibrinogen stress responses than less happy participants. This difference in inflammatory response is potentially important in the light of the role of fibrinogen in stimulating atherosclerosis and platelet aggregation.

In summary, these findings indicate that greater positive affect is associated with reduced activation of neuroendocrine, cardiovascular and inflammatory processes that are relevant to health. The fact that differences were independent of psychological distress suggests that positive well-being may have a relationship with biology that is separate from that of negative affect. We can speculate that these biological responses could mediate the relationship between physical health outcomes and positive affect, and that small but persistent differences in physiological activation with happiness might ultimately impact on physical disease risk, especially in old age. However, it should be emphasized that findings were cross-sectional, so no causal conclusions can be drawn. Additionally, participants were all in good health, and no objective markers of physical illness were recorded.

5. Longitudinal associations

We have recently had an opportunity to assess the consistency of the associations between happiness and biological function in everyday life in a longitudinal study. Three years after the original ambulatory monitoring phase, 162 of the 216 participants agreed to a further round of assessment. The majority of people who were not retested had either withdrawn from the full Whitehall II study, had moved out of the London area so were no longer accessible, or refused because they had found the procedure to uncomfortable. A small

number had died or developed serious medical problems, such as cancer. We found no differences in participation rate at 3 years in relation to age, gender, GHQ or happiness scores at the time of the original study (Time 1). The Time 2 participants undertook a day of ambulatory blood pressure and heart rate monitoring in the same way as before. Each reading was accompanied by a rating of happiness on the five-point scale, so that the stability of positive affect could be analyzed. The saliva sampling schedule was reduced, and instead of eight readings at 2 h intervals as at Time 1, measures were obtained at 10:00–10:30, 16:00–16:30 and 20:00–22:30 h.

The biological correlates of happiness were remarkably stable over this 3 year period. The cortisol results are plotted in Fig. 2, showing mean levels for the happiness quintiles defined on the basis of the Time 1 working day. After adjustment for age, gender, grade of employment, smoking and BMI at follow-up, GHQ score, and whether or not the person was still in paid employment, the gradient across happiness quintiles approached significance ($p=0.070$). The adjusted difference between the highest and lowest quintiles was 20%, somewhat less than at Time 1, but still substantial. We also recorded an association between heart rate at follow-up and

Time 1 happiness quintile in men ($p=0.016$). Heart rate in the lowest happiness quintile averaged 74.5 ± 6.4 bpm after adjustment for covariates, compared with 68.4 ± 9.3 bpm in the happiest quintile, a difference of 5.9 bpm.

The 3 year follow-up analyses revealed a new effect that was not present at Time 1. There was a significant inverse association between happiness and ambulatory systolic blood pressure averaged over the day and evening ($p=0.030$). The difference was significant after adjusting not only for the covariates detailed above, but also for the use of antihypertensive medication (see Fig. 2). The adjusted difference between high and low quintiles of 5.72 mm Hg was substantial, and suggests that as participants grow older, positive well-being becomes associated with blood pressure in everyday life as well as with cortisol and heart rate.

6. Conclusions

This analysis of 3 year follow-up data from our original study group suggests that the associations between biological responses and happiness are quite robust. The cortisol gradient across quintiles of happiness was similar to that observed at Time 1, although the strength of relationship was reduced. The smaller sample size may account in part for this diminution of statistical power. However, the consistency is impressive, bearing in mind that the activities of a typical day had greatly altered over the intervening period for many participants. For example, about 10% had retired during the intervening years. Similarly, the gender difference in the relationship between heart rate and happiness persisted. Raised heart rate is an independent risk factor for mortality and cardiovascular disease, and in the Framingham study was shown to be a more reliable indicator in men than women [4]. Most interesting of all was the emergence of an association between happiness and systolic blood pressure. It should be noted that blood pressure was not measured with casual readings in the clinic, but by averaging up to 35 readings over the day and evening. This increases our confidence in the reliability of the estimate for each individual. The association between greater happiness and lower systolic pressure was independent of factors, such as smoking, body mass and socioeconomic position that are also known to affect pressure levels. It also remained significant after adjustment for negative affect, so was not a reflection of the known relationship between negative affective states and elevated blood pressure [3]. However, we do not know why the effect was not present at the time of initial assessment and only emerged 3 years later. It is possible that advancing aging is responsible. In summary, our findings indicate that positive affect is related to favorable profiles of functioning in several biological systems, and may thereby be relevant to the development of physical illness. We intend that participants in this study will continue to have their health monitored into the future, so we will be able to study relationships between happiness and objective health outcomes as they evolve over the coming years.

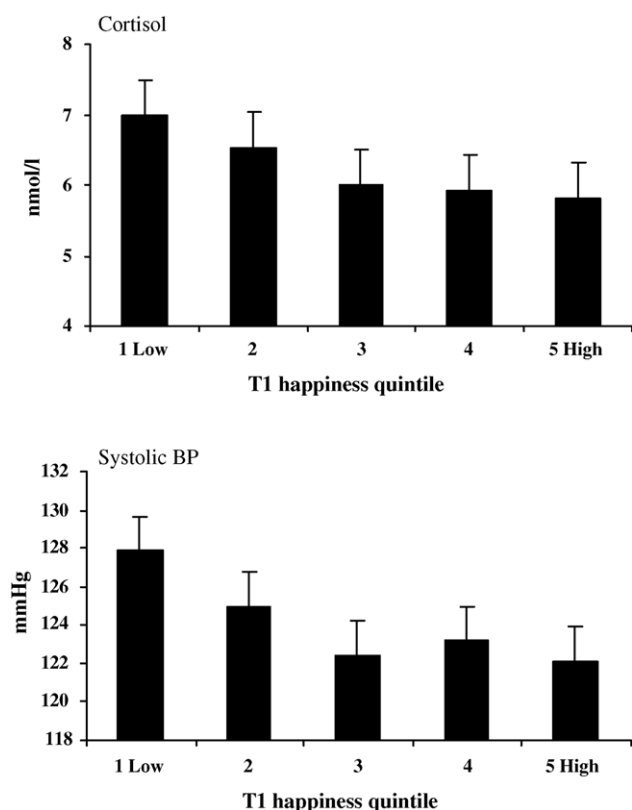


Fig. 2. Mean salivary cortisol (upper panel) and systolic blood pressure (lower panel) averaged over the day and evening at 3 year follow-up, classified according to happiness quintile defined at Time 1. Cortisol values are adjusted for age, gender, grade of employment, smoking and body mass index at follow-up, GHQ scores, and whether or not the participant was working at follow-up. Blood pressure values are adjusted for these factors and in addition for use of antihypertensive medication. Error bars are S.E.M.

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