Understanding the Links between Positive Wellbeing and Health

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Declaration

I, Jennie Brown, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed

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Abstract

People with higher levels of positive wellbeing may enjoy better health and live longer, but it is not clear why. This thesis explores the notion that links between positive wellbeing and health-relevant biological correlates could provide some explanation for the relationship between positive wellbeing and health. Two complementary approaches were used. First, associations between the positive personality trait of resilience (the ability to withstand chronic stress or adversity) and various biological and psychological factors were explored using secondary data. Second, an intervention study was used to test causal mechanisms between changes in positive wellbeing and changes in biology.

Resilience (from the Resilience Scale), psychosocial stressors and affect and wellbeing outcomes were assessed in around 200 healthy working women as part of the Daytracker study. Measures of cortisol and heart rate variability (HRV) were also collected across a work and leisure day. Results of regression analyses suggested that higher resilience was associated with greater HRV across the work period, but there was no association with cortisol. Resilience mediated the relationship between particular stressors and affect and wellbeing outcomes.

A two week gratitude-based intervention in 119 healthy women was used to try to increase positive wellbeing. Psychological and biological factors (cortisol, blood pressure and heart rate) were assessed before and after the intervention. The gratitude condition was associated with increased optimism, reduced depressive symptoms and lower diastolic blood pressure. However, associations with measures of positive wellbeing were not robust. It was therefore not possible to demonstrate causal links between changes in positive wellbeing and changes in biology. Future studies could focus on strengthening positive wellbeing intervention tasks.

Overall the results provided modest evidence for links between positive wellbeing and biological correlates of health. Resilience may provide cardiac health protective effects, since reduced HRV has previously been associated with increased cardiovascular disease incidence.

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1 Positive wellbeing and health: an overview

1.1 Introduction

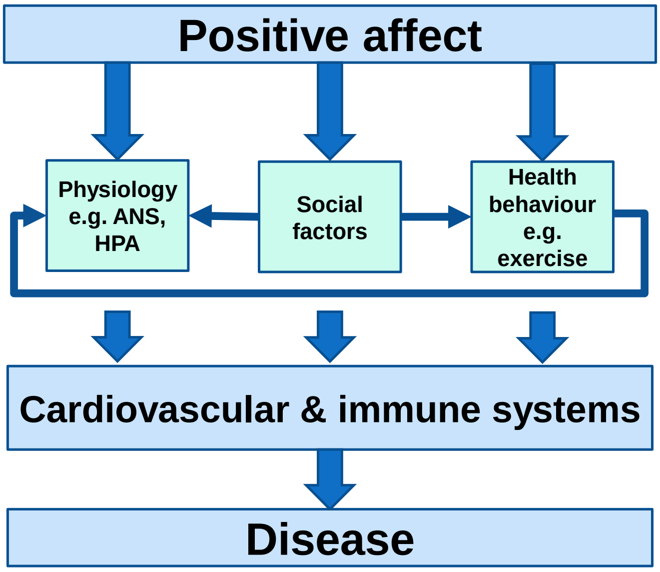
According to the World Health Organization (1948), health may be defined as: "...a state of physical, mental and social well-being, not merely the absence of disease and infirmity." Thus, striving towards health involves something that goes above and beyond a neutral state characterised by a lack of illness. Positive wellbeing is a concept which concurs with this idea because it describes a state of mental health that is more positive than a baseline, neutral level. The term 'positive wellbeing' covers a wide field of research from personality traits to affective states and mental health. Examples include the study of positive affect, optimism and satisfaction with life. As a relatively recent line of psychological enquiry, the study of positive wellbeing offers an opportunity to study the benefits of good mental wellbeing. This may provide a new avenue for both treatment and prevention of mental health issues.

The traditional, medical perspective towards mental health has focussed on diagnosing, understanding and treating psychological disorders, with less attention towards preventative measures. Reducing the impact of mental illness is important not only for the relief of psychological distress, but also for physical health, since the link between mental and physical health is becoming increasingly apparent. For example depression has been associated with increased risk of obesity, cardiovascular disease (CVD) and even cancer (Luppino et al., 2010; Rugulies, 2002; Spiegel & Giese-Davis, 2003). Thus preventative measures to combat mental illness may also impact upon physical health.

The influence of cognitive processes on nervous and hormonal activity may underlie the connection between mental and physical health. For example stress and depression have been associated with increased activity of the sympathetic nervous system (or SNS, a branch of the autonomic nervous system) and with dysregulation of the hormone cortisol. Such changes in biological processes have in turn been related to increased risk of health problems. Therefore, investigating psycho-biological links will help to determine a possible route for the influence of mental states on health.

There is growing evidence that greater positive wellbeing is associated with increased longevity and better cardiovascular health (see section 1.4). However, the reasons for this are not yet clear. Relationships between positive wellbeing and health could be direct (e.g. via genetic linkage) or indirect. Figure 1.1 depicts a theoretical model showing possible indirect routes (adapted from Pressman & Cohen, 2005). In this model, positive affect may influence physiological factors such as the autonomic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis which are responsible for the regulation of cortisol. Any changes in physiology could then impact on the regulation of bodily systems such as the cardiovascular system that in turn may influence health. Pressman and Cohen (2005) acknowledge that this process is unlikely to occur in isolation. Other factors relevant to both positive affect and bodily systems may also influence health outcomes: for example, health behaviours and social factors.

The studies presented in this thesis offer a focus on an important part of the model in figure 1.1; specifically, the links between positive wellbeing and physiology (i.e. biological indicators of health) with consideration given to the role of health behaviour. Associations between factors such as SNS activity or cortisol and health have been relatively well established, so by investigating links between positive wellbeing and biology (which is poorly understood) we may be able to understand whether positive wellbeing has the potential to be health protective.



Key: ANS = autonomic nervous system, HPA = hypothalamic-pituitary-adrenal axis.

Figure 1.1: A theoretical model of the influence of positive affect on disease (adapted from Pressman & Cohen, 2005).

When exploring health protective concepts, the trait of resilience (the ability to withstand high levels of stress or adversity) is a particularly useful area of investigation. Because greater resilience is associated with both lower levels of stress and depression, as well as greater positive wellbeing, it is ideally suited for exploring the inter-relationships between positive wellbeing, stress and biology simultaneously. A small number of studies suggest that resilience may be related to beneficial health outcomes. However, little is known about the connection between resilience and biological indicators of health.

The first part of this thesis seeks to explore such connections. Since resilience and stress are inversely related it is expected that greater resilience will be associated with biological factors indicative of lower stress e.g. lower cortisol output and reduced SNS activity (which in turn are associated with reduced risk of health issues such as CVD). If there is a link between resilience and biology this has an implication towards identifying people with low resilience as being at possible risk of future mental and physical health problems.

People at risk for health problems might benefit from interventions designed to increase positive wellbeing. The practice of activities designed to elicit positive feelings could be helpful because positive emotions are thought to contribute towards building resilience (Fredrickson, 2001, 2004). The development of positive psychology based interventions is an exciting new area for preventative health. Such interventions are specifically focussed on increasing positive wellbeing via exercises such as expressing gratitude, performing random acts of kindness and recalling positive past events. Such interventions are reported to increase measures of positive wellbeing and reduce symptoms of mental illness (Sin & Lyubomirsky, 2009). However, very few intervention studies have included objective measures of physical health hence making their impact on biology difficult to assess. It is important to know if increasing positive wellbeing has a causal effect on changes to biology because this will help to demonstrate a possible link between positive wellbeing and health. Therefore, the second part of this thesis presents the results of a brief positive psychology based intervention where a range of psychological and biological factors were assessed.

There are two main methodological approaches in this thesis: 1) a cross-sectional design using secondary data to explore associations between resilience and a number of psychological and biological variables and 2) an intervention study to assess causal links between positive wellbeing and biology. By using two different, yet complimentary approaches, I aim to strengthen our understanding of the link between positive wellbeing and biology – a vital explanatory route for clarifying positive wellbeing and health associations.

Chapter 1 sets out the overarching theoretical background for this study of positive wellbeing and the biological correlates of health. This forms the basis for the more specific rationale and hypotheses in the experimental chapters. Inconsistencies in the literature and issues relating to psychological and biological measurement are discussed. It should be noted that resilience is reviewed separately in the next chapter as it relates to the first part of this thesis (whereas positive wellbeing is relevant to the whole thesis).

1.2 What is positive wellbeing?

Seligman and Csikszentmihalyi's (2000) seminal issue on positive psychology in American Psychologist is often regarded as the starting point for positive psychology as a specific area of scientific interest. Seligman defines positive psychology as: "The scientific study of the strengths and virtues that enable individuals and communities to thrive" (Seligman & Csikszentmihalyi, 2000, p 5). Prior to 2000, there had been growing interest in positive psychology following observations that certain people managed to cope with the appalling conditions of World War II, whereas others did not. Additionally, developments in humanistic psychology (founded by Maslow and Rogers in the 1960s) suggested a holistic approach to psychological wellbeing and introduced concepts relevant to positive psychology such as developing a meaningful life. The lack of empirical evidence for humanistic concepts and the growing interest in 'self-help' did not improve the credibility of early ideas in positive psychology. Recent research in positive psychology adopts a more scientific approach with an emphasis on prevention and health promotion. However, because this field is still in its infancy, key terms such as positive wellbeing are still being defined and conceptualised.

Two distinct interpretations of positive wellbeing have been suggested. The first describes subjective wellbeing (also called hedonic wellbeing) which includes evaluation of positive and negative affect (either as state or trait measures) and cognitive evaluations of life satisfaction. High levels of subjective wellbeing are therefore characterised by high positive affect, low negative affect & high life satisfaction (Diener, Suh, Lucas, & Smith, 1999). The second interpretation is termed eudaimonic wellbeing (Ryff & Singer, 1996). This is a more global, holistic and multi-dimensional perspective, which includes aspects such as self-acceptance and purpose in life. Other aspects of positive wellbeing include optimism (having a more positive outlook on life) and the Japanese term "ikigai" which is translated as "a reason for being". This thesis will concentrate on the former concept of subjective wellbeing with particular emphasis on affect. However, studies including eudaimonic measures such as psychological wellbeing are included in the literature review due to a paucity of research in positive wellbeing and biology.

The affective component of subjective wellbeing is an important area of study, since positive affect can be measured both as a momentary state and over longer time frames, e.g. across several weeks. Affect may be defined as the conscious experience of an emotion, whereas emotion may be seen as umbrella term for the behavioural, expressive, cognitive and physiological changes that occur during a particular state (Panksepp, 2000). However, the terms affect and emotion are often used interchangeably. A commonly used conceptualisation of affect describes affective states as measurable across two dimensions: valence (positive, negative or neutral) and arousal or strength of feeling (Lang, Greenwald, Bradley, & Hamm, 1993; Russell, 1980). According to this model, positive states include those with relatively high levels of arousal and positive valence (e.g. happiness, elation and cheerfulness), and states with lower levels of arousal such as being content or at ease (Averill, 1997; Larsen & Diener, 1992).

Just as positive wellbeing is not merely a lack of mental illness, positive affect cannot be defined as the polar opposite to negative affect, although they are inversely related (Diener & Emmons, 1984). Despite this, positive wellbeing is sometimes defined as the absence of negative affect or symptoms of mental ill health, rather than measuring it directly as a psychological construct. There is a danger of circular reasoning, for example, if a lack of mental illness is used to characterise a state of wellbeing, and this state of wellbeing is then evoked as the explanation for robust mental health under particular conditions. Studies of positive wellbeing therefore benefit from the direct measurement of positive affective states or traits. Measurement issues are particularly relevant to this thesis, because findings may differ according to method of positive wellbeing assessment (as discussed in section 1.4). For this reason, various measures are used in the studies presented in the following chapters.

The importance of momentary positive states in psychological wellbeing is set out in Fredrickson's (2001) 'Broaden-and-Build' theory of positive emotions. In this theory, positive emotions play two crucial roles in mental wellbeing. The first role is to encourage a broader mindset or "thought-action repertoire", for example by increasing creativity, play, openness to new experience and social contact. The increase in such behaviours promotes the second role: the ability to build better personal resources, including social support and a reserve of cognitive and emotional strategies, which may help to increase resilience to stress and negative events in the future. The broader mindset and improved personal and cognitive resources then further increases the experience of positive emotions. Positive emotions are therefore thought to set off an 'upward spiral' of improved positive wellbeing for the future (Fredrickson, 2004).

1.3 Factors contributing to positive wellbeing

Aside from the experience of positive emotions, a number of other factors are thought to influence the development and the level of positive wellbeing within an individual. According to Lyubomirsky, Sheldon and Schkade (2005b), individual differences in subjective wellbeing can be accounted for by 50% genetics, 10% life circumstances and 40% intentional activities (although there are other contributing factors). This means that although a certain amount of positive wellbeing may be pre-determined, there is also substantial scope to change.

1.3.1 Genetics

Lyubomirsky et al's (2005b) genetic contribution estimate comes from twin studies suggesting that 40% to 50% of individual differences in subjective wellbeing are attributable to genetics, with heritability at approximately 80% (Bartels & Boomsma, 2009; Lykken & Tellegen, 1996; Nes, Røysamb, Tambs, Harris, & Reichborn-Kjennerud, 2006; Stubbe, Posthuma, Boomsma, & De Geus, 2005). Nes et al (2006) also assessed the stability of subjective wellbeing ratings over time. They found a correlation of about 0.5 between ratings of wellbeing at baseline and 6 years later. Long term stability of ratings was suggested to be due to genetics, whereas changeability in ratings was attributed to environmental factors i.e. life events. Nes et al argue that their findings provide evidence for the 'set point' theory of wellbeing, whereby the influence of life events can change subjective wellbeing in the short term, but in most people levels of wellbeing eventually return to a (genetically determined) set point.

1.3.2 Personality

Individual differences in personality have also been linked to positive wellbeing. Traits from the Five Factor Model of personality (McCrae & Costa, 1987), including extraversion, conscientiousness and neuroticism were associated with subjective wellbeing in meta analyses (DeNeve & Cooper, 1998; Steel, Schmidt, & Shultz, 2008). Weiss, Bates and Luciano (2008) suggest a common genetic basis as a linking factor between high levels of subjective wellbeing, low neuroticism and high extraversion, conscientiousness, openness and agreeableness.

Other personality traits have close associations with higher levels of positive wellbeing. For example, resilience has been found to correlate highly with various measures of positive wellbeing including positive affect and psychological wellbeing (e.g. Cohn, Fredrickson, Brown, Mikels, & Conway, 2009; Lyubomirsky, King, & Diener, 2005a). Resilience is thought to influence wellbeing by ameliorating some of the negative impacts of stress on mental (and possibly physical) health. The relationship between resilience, positive wellbeing, and mental and physical health is outlined in detail in the Chapter 2 as it forms the basis of three studies presented in this thesis.

1.3.3 Life circumstances

A range of demographic, psychosocial and socioeconomic factors are suggested to contribute towards wellbeing, such as age, marital status and income. According to a worldwide poll, older people report less satisfaction with life, apart from in the richest countries, including the UK (Deaton, 2008). In the wealthier countries there appears to be a U-shaped relationship with a slight decrease in life satisfaction in middle age. Being married also seems to be linked to wellbeing. Myer's (2000), report on the wellbeing of

35 000 people as part of the General Social Survey in the USA revealed that both married men and women were happier than those who were never married, divorced or separated.

Myer (2000) also found that despite a very large increase in inflation adjusted income in the US since 1956, levels of happiness had remained more or less the same over time. A similar pattern was found in the UK between 2002 and 2011 for income and life satisfaction (Self, Thomas, & Randall, 2012). Comparisons across different countries for the relationship between income and wellbeing reveal a slightly different pattern. People with lower incomes report less happiness, but only up to a certain limit; beyond an annual income of US$75 000 the relationship is lost (Kahneman & Deaton, 2010). Kahneman and Deaton suggest that the negative impact of a low income is more important to emotional wellbeing than the benefits of having a higher income. Despite this, several countries with comparatively low gross domestic product (GDP) such as Venezuela, Costa Rica and Panama featured in the top 20 countries by wellbeing score according to the New Economics Foundation (Abdallah, Michaelson, Shah, Stoll, & Marks, 2012). There are clearly other factors which are important to wellbeing such as intentional activities.

1.3.4 Intentional activities

'Intentional activities' in the context of wellbeing describes behaviours or cognitions which are purposefully used to increase positive feelings. Examples of such activities include performing acts of kindness by helping others, expressing gratitude and savouring positive experiences (Lyubomirsky & Layous, 2013). These kinds of behaviour can be observed in people who already enjoy good mental wellbeing and so have formed the basis of a number of interventions designed to increase positive wellbeing (Sin & Lyubomirsky, 2009). The use of positive psychology based interventions is discussed in the latter part of this dissertation along with the results from our intervention (the Wellbeing study).

In order to capture the complexities of positive wellbeing it will be helpful to consider the influence of some of the contributing factors discussed in this section. The personality trait of resilience and the role of intentional activities are the main aspects explored in this thesis. Factors such as income and age have also been acknowledged in the analyses. By combining evidence from these areas, the studies in this thesis will contribute towards a more holistic understanding of positive wellbeing and relationships with biology.

1.4 Positive wellbeing and biological correlates of health

The association between mental illness and poor physical health, such as the link between depression and coronary heart disease has been well documented (e.g. Rugulies, 2002). Higher levels of positive wellbeing are associated with better mental health and reduced susceptibility to psychological disorders such as depression (Southwick, Vythilingam, & Charney, 2005). However, research into the potential impacts of positive wellbeing on physical health is still in its infancy.

An area that has received some attention is the link between positive wellbeing and longevity. A meta-analysis of 35 studies by Chida and Steptoe (2008) demonstrated that positive wellbeing was related to reduced mortality in both healthy people (overall combined hazard ratio = 0.82) and people with existing diseases (hazard ratio = 0.98, where numbers less than 1 indicate reduced risk of mortality within a study period). Hazard ratios were still significant in the healthy population when including only studies of cardiovascular mortality and in studies controlling for negative affect. However, there was an indication of publication bias in favour of positive results being more likely to be published. There have been a number of large well-controlled studies since 2008 showing similar results, so the evidence in this area is strengthening. For example, measures of positive affect, life satisfaction and subjective wellbeing have all been linked to reduced mortality rates (Prinsloo et al., 2014; Steptoe & Wardle, 2011; 2012; Wiest, Schüz, Webster, & Wurm, 2011; Xu & Roberts, 2010).

One potential explanation for the link between positive wellbeing and longevity could be that people with greater positive wellbeing enjoy better cardiovascular health. Several large, well controlled studies found reduced incidence of CVD in people with greater positive wellbeing (Boehm, Peterson, Kivimaki, & Kubzansky, 2011b; Davidson, Mostofsky, & Whang, 2010; Hawkins, Callahan, Stump, & Stewart, 2014; Kubzansky & Thurston, 2007; Ostir, Markides, Peek, & Goodwin, 2001). However, not all studies agree. A lack of association between CVD incidence and positive affect has also been reported (Freak-Poli et al., 2015; Nabi et al., 2008b). These latter studies were equally well controlled and sizeable compared with the studies reporting significant results.

A possible reason for these disparities could be method of measurement for positive wellbeing. For example, Kubzansky and Thurston (2007) and Boehm et al (2011b) used a measure of emotional vitality, whereas Davidson et al (2010) used a clinically assessed measure of positive affect. Moreover, Freak-Poli et al (2015) measured positive affect using a 4-item subscale of the Center for Epidemiologic Studies-Depression (CES-D) scale and Nabi et al (2008a) used the Bradburn Affect Balance Scale. Perhaps these measures are not similar enough to be directly compared or general measures of positive wellbeing and specific measures of positive affect are assessing different concepts.

Even if some studies report protective effects of positive wellbeing on mortality and CVD, potential causal mechanisms are yet to be fully established. As set out in section

1.1, possible indirect explanatory routes include the influence of positive states and traits on biological processes relevant to health (discussed below) and an increased likelihood for adopting health protective behaviours (see section 1.5).

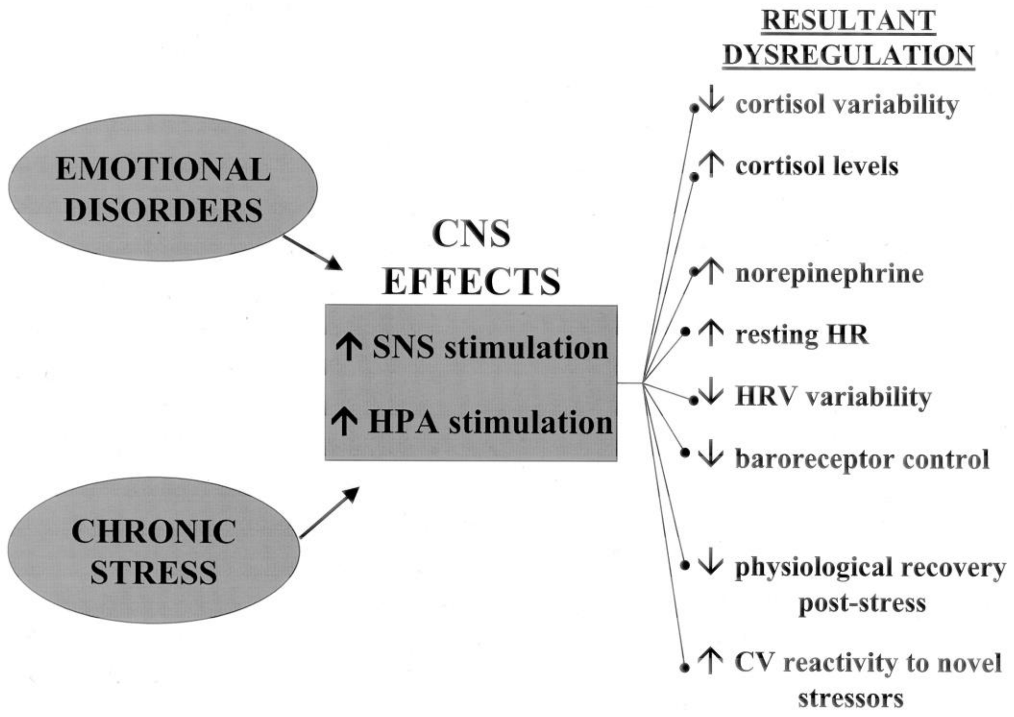
1.4.1 Psychobiological links

To explore the links between positive wellbeing and biology, it is first necessary to understand how the brain and body are connected. Links between psychological and biological processes can be understood by the direct and indirect influence of cortical and sub-cortical brain activity on the autonomic nervous system (ANS) and hormones. During emotional arousal, the reciprocal relationships between the limbic system (particularly the amygdala) and cortical areas (such as the pre-frontal cortex) play an important role in the regulation of physiological responses (Andreassi, 2007). Brain activity is linked to bodily systems via the two branches of the ANS: the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS). The SNS and PNS innervate and influence the activity of numerous organs within the body, including vital biological systems such as the cardiovascular system. Broadly speaking, the SNS functions to prepare the body for mobilisation and energy expenditure, while greater activity of the PNS is implicated during periods of rest and restorative processes. For example, greater activity of the SNS is associated with increasing heart rate, whereas greater PNS activity slows heart rate. Thus, the functional effects of the SNS and PNS tend to be antagonistic, although they can also function synergistically (Thayer, Hansen, & Johnsen, 2010).

Another psychobiological link involves the release of corticotrophin-releasing hormone (CRH) the hypothalamus (the activity of which is influenced by other limbic and cortical regions). This triggers a series of chemical events, as seen in the hypothalamic-pituitary-adrenal (HPA) axis response. CRH activates the pituitary glands to secrete adrenocorticotropic hormone (ACTH) which in turn increases cortisol production in the adrenal cortex.

Changes to hormonal regulation and ANS activity following emotional arousal can have a number of effects on the body. For example, the effects of chronic stress and/or emotional disorders such as depression may include increased activity of the HPA axis and the sympathetic branch of the ANS (Belmaker & Agam, 2008). This increased stimulation of the SNS and HPA axis can have a number of effects on the regulation of various bodily systems such as heart rate, baroreceptor control (for blood pressure regulation) and cortisol (Rozanski & Kubzansky, 2005), as depicted in Figure 1.2.

The influence of positive psychological states on biological processes is not yet clearly understood. Positive states and traits have been associated with greater activity of the PNS and/or reduced activity of the SNS, along with reduced cortisol output. However, this is not always the case. There is also the added complication that emotions with high arousal (whether positive or negative) may elicit similar biological responses, so it is not necessarily true that the effects of positive wellbeing on biology are opposite to those of negative states.



Key: CNS = central nervous system, SNS = sympathetic nervous system, HPA = hypothalamic-pituitary-adrenal, HR = heart rate, HRV = heart rate variability, CV = cardiovascular

Figure 1.2: Possible effects of emotional disorders and/or chronic stress on the central nervous system (CNS) and examples of resultant dysregulation of physiological processes (from Rozanski & Kubzansky, 2005, p S51, with permission)

The following sections introduce the biological correlates assessed in this thesis. Previous research on positive wellbeing and biology is discussed and methodological issues identified for review. It should be noted that there are many health relevant biological factors e.g. markers of immune function, cholesterol etc. However, only cortisol and cardiac measures (including heart rate and blood pressure) are assessed in later chapters in this thesis. These measures were chosen as they are non-invasive, relatively easy to administer to large numbers of participants and are relevant to both stress and health.

1.4.2 Cortisol

During the stress response, production of cortisol may increase above typical daily levels, affecting many physiological processes (e.g. glucose metabolism) in such a way as to prepare the body for action. Perceived stress influences cortisol levels via the complex series of hormonal events in the HPA axis. A negative feedback mechanism serves to bring the body back to baseline levels of cortisol once the stressor has subsided (Ader, Felten, & Cohen, 2001).

Cortisol can be measured in blood, urine, saliva and hair samples. Salivary cortisol is the least invasive measure for assessing momentary cortisol. Albeit less accurate than blood serum levels, it is much better suited to large studies where a number of measurements throughout the day are required (Hellhammer, Wüst, & Kudielka, 2009). Also, salivary cortisol measures are more stable at room temperature when compared to blood samples, which reduces the need for refrigeration and rapid transportation to the laboratory for analysis (Aardal & Holm, 1995).

Common salivary cortisol measurements include assessing the total volume produced over the course of a day, measuring the difference between the waking concentration and peak concentration 30 minutes after waking (or the cortisol awakening response, CAR), and calculating the cortisol slope or mean rate of change across the day. These measurements are depicted in Figure 1.3, which shows an idealised cortisol profile over the day. Separating the cortisol profile into components is important as the regulatory mechanisms behind the CAR are different from those influencing cortisol levels for the rest of the day (Schmidt-Reinwald et al., 1999; Wilhelm, Born, Kudielka, Schlotz, & Wüst, 2007).

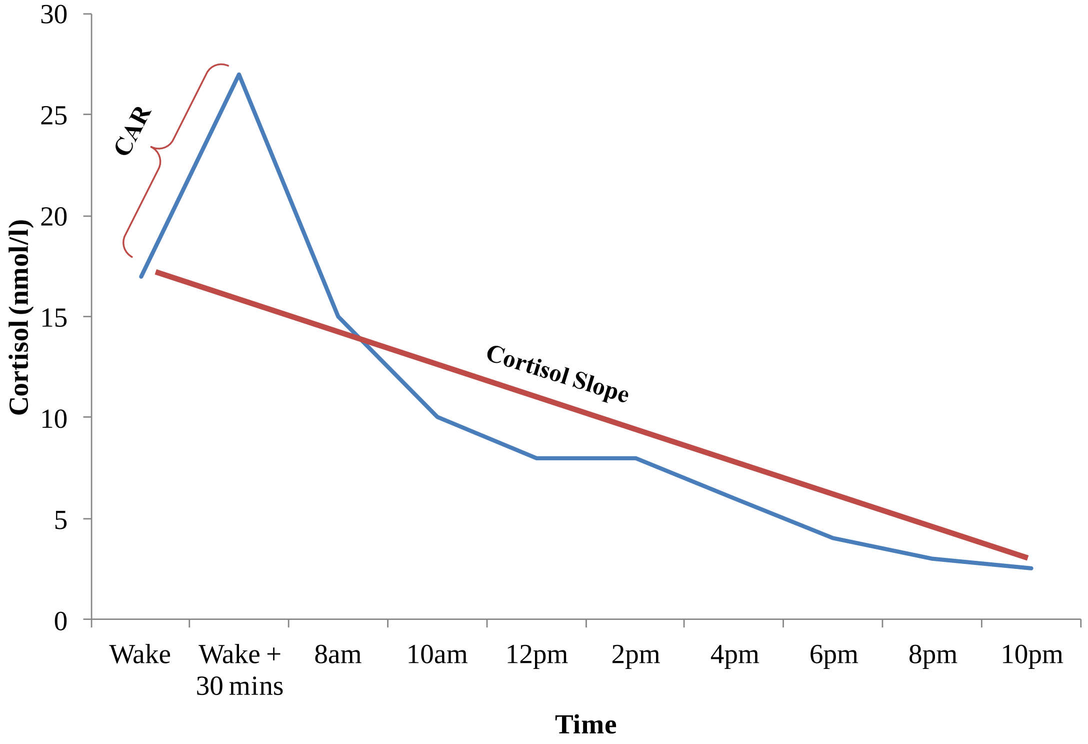


Figure 1.3: An idealised cortisol profile over the day.

(CAR = cortisol awakening response)

The purpose and regulation of the CAR is not clearly understood, although it has been theorised as preparing the body in anticipation of the demands of the day. It is also associated with the transition from sleep to consciousness including activating memory and spatio-temporal processes in the brain (Adam, Hawkley, Kudielka, & Cacioppo, 2006; Chida & Steptoe, 2009; Clow, Hucklebridge, Stalder, Evans, & Thorn, 2010; Fries, Dettenborn, & Kirschbaum, 2009). Additionally, the CAR is partly genetically determined (Wüst, Federenko, Hellhammer, & Kirschbaum, 2000) and does not always correlate with cortisol secretion during the rest of the day, depending on how it is assessed (Edwards, Clow, Evans, & Hucklebridge, 2001; Schmidt-Reinwald, et al., 1999).

There is considerable variability in absolute values for the CAR between individuals. This may be due to the many confounding factors which can affect the awakening response including gender, age, smoking, whether the CAR is measured during a work or leisure day, and factors concerning participant adherence to collection times (Clow, Thorn, Evans, & Hucklebridge, 2004; Smyth, Clow, Thorn, Hucklebridge, & Evans, 2013). There are also a number of different ways to calculate the CAR; including the area of under the curve (AUC) to estimate total cortisol output during the CAR, and assessing change in cortisol by subtracting the waking value from the post awakening value (see Clow, et al., 2004).

Measuring the cortisol slope has received greater attention recently since several studies have suggested links between flatter cortisol slopes and poorer mental and physical health (discussed in greater detail in Chapter 5). Steeper cortisol slopes are thought to be indicative of an optimal cortisol profile, since cortisol levels are declining more rapidly after the peak value has been reached. Again, there are different ways to assess the cortisol slope. For example, some studies do not include the waking sample or the initial rise after waking in their calculations depending on the formula used and the nature of the investigation.

1.4.2.1 Cortisol, stress and health

Acute stress tends to increase cortisol levels above regular daily levels, but under chronic stress different patterns of cortisol regulation may be observed. In a meta-analysis, Miller, Chen and Zhou (2007) report that across 107 studies since 1950, both elevated and blunted cortisol responses have been related to chronic stress. These differences in finding were attributed to various factors including the nature of the stressor and the time since onset. The results of this meta-analysis suggest that overall chronic stress exposure is associated with greater total cortisol output across the day, flatter cortisol slopes and lower morning cortisol concentrations. However, Chida and Steptoe (2009) reported positive associations between job stress and CAR, and between general life stress and CAR, following a meta-analysis.

These opposing findings might be caused by a number of reasons. For instance, Miller et al do not specify whether they included assessments of CAR as part of their overall measure of 'morning cortisol' and in fact do not mention the CAR at all in the text of their paper. Perhaps morning cortisol was a single sample taken at some point in the morning (most likely on awakening), although again this was not specified. Miller et al also suggest that morning cortisol concentrations tend to be lower in people experiencing chronic stress, whereas levels throughout the rest of the day tend to be higher. It may be that the greater CAR as reported by Chida and Steptoe may mark the start of the elevated levels seen across the rest of the day in people with chronic stress but that absolute cortisol concentrations on waking may be lower. Also common measures of CAR assess the *change* in cortisol from waking to 30 minutes after waking. Hence they may not be comparable to a single morning sample of cortisol.

Producing small amounts of cortisol following acute stress may be advantageous because it has anti-inflammatory effects, speeds tissue repair and controls excess immune cell production (Sapolsky, Romero, & Munck, 2000). However, chronic dysregulation of cortisol has been associated with changes in regular bodily function including higher blood lipid levels, poor glucose regulation and immune system suppression (McEwen, 2007). As a result of these imbalances in regular bodily function, people with chronic raised cortisol levels have an increased risk of hypertension (continuously raised high blood pressure), type 2 diabetes (caused by insulin resistance), obesity, and autoimmune diseases (Björntorp & Rosmond, 2000, 2006; Epel et al., 2000; Heijnen & Kavelaars, 2005; Kelly, Mangos, Williamson, & Whitworth, 2007).

Higher cortisol levels and flatter cortisol slopes have also been associated with increased incidence of CVD and cardiovascular mortality and all cause mortality rates both in healthy and diseased populations (Kumari, Shipley, Stafford, & Kivimäki, 2011; Manenschijn et al., 2013; Matthews, Schwartz, Cohen, & Seeman, 2006; Reynolds et al., 2010; Sephton et al., 2012; Sephton, Sapolsky, Kraemer, & Spiegel, 2000; Vogelzangs et al., 2010; Yamaji et al., 2009). The range of potential diseases associated with excess cortisol production is fairly extensive due to the action of cortisol over a range of metabolic functions and bodily systems, plus the sensitivity of the HPA axis to both internal and external changes (McEwen, 2007). Thus, measuring cortisol may give an indication of both the stress response and a marker of potential future health risks.

Cortisol dysregulation has also been linked to poorer mental health. Depression is thought to be associated with hyperactivity of the HPA axis, as seen by increased cortisol in people with major depression, compared to healthy populations (Stetler & Miller, 2011). Investigations of specific cortisol components have so far yielded fairly mixed results. For example, depression has been associated with both increased and reduced CARs (Bhagwagar, Hafizi, & Cowen, 2005; Ellenbogen, Hodgins, Walker, Couture, & Adam, 2006; Pruessner, Hellhammer, Pruessner, & Lupien, 2003b; Stetler & Miller, 2005). Chida and Steptoe (2009), suggest that this inconsistency may be due to differences in the measurement of depression and inclusion of sufficient control factors.

Flatter cortisol slopes have been reported in men with severe depression (Deuschle et al., 1997), in depressed patients with coronary artery disease (Bhattacharyya, Whitehead, Rakhit, & Steptoe, 2008), and in studies of depressive symptoms in healthy populations (Knight, Avery, Janssen, & Powell, 2010; Sjögren, Leanderson, & Kristenson, 2006). However, other studies report no difference in cortisol slope in people with and without major depressive disorder (e.g. Peeters, Nicolson, & Berkhof, 2004; Stetler, Dickerson, & Miller, 2004). Additionally, a study of 990 healthy men and women found a lack of association between depressive symptoms and cortisol slope, CAR and total cortisol (Lederbogen et al., 2010).

1.4.2.2 Cortisol and positive wellbeing

Several naturalistic studies using momentary measures of positive affect have found inverse associations between positive wellbeing and total cortisol output. For example, Smyth et al (1998) reported lower mean daily cortisol concentration in participants with higher positive affect scores. Similarly, among 216 civil servants from the Whitehall II study cohort, lower total daily cortisol concentrations were found in people reporting more frequent happy mood across the monitoring day (Steptoe, Wardle, & Marmot, 2005).

In a study of 298 men and women, Polk, Cohen, Doyle, Skoner, & Kirschbaum (2005), reported that greater *state* positive affect was associated with lower total cortisol concentrations in women but not men, and greater *trait* positive affect was associated with steeper cortisol slopes in men but not women. However, positive associations between subscales of the Psychological Wellbeing Scale and steeper cortisol slope have been demonstrated in elderly women (Ryff et al., 2006). Therefore, there may be both gender differences in the positive wellbeing-cortisol relationship and differences in finding according to type of positive wellbeing measurement.

There is conflicting evidence among studies which have measured both diurnal cortisol and the CAR. Some studies report significant inverse relationships between positive affect and diurnal cortisol but not for the CAR, including both generalised and momentary measures of positive affect (Lai et al., 2005; Steptoe, O'Donnell, Badrick, Kumari, & Marmot, 2008). Other studies suggest that greater positive affect may be specifically associated with reduced cortisol levels earlier in the day but not later on. Higher positive affect scores from ecological momentary assessment (EMA), where state affect is assessed at a number of times across the day, were inversely related to the CAR (Steptoe, Gibson, Hamer, & Wardle, 2007). However, positive affect was not related to cortisol levels later in the day. Higher positive affect (measured using a combination of 3 different scales) was associated with a reduced CAR, but again not to later cortisol levels (Brummett, Boyle, Kuhn, Siegler, & Williams, 2009). Similarly, inverse relationships between the CAR and optimism have been reported, but no association between optimism and the diurnal cortisol profile (Endrighi, Hamer, & Steptoe, 2011; Jobin, Wrosch, & Scheier, 2014).

In contrast, Lindfors and Lundberg (2002), demonstrated an association between higher positive wellbeing (as assessed using the PWB scale) and lower total cortisol output both across the day *and* in a separate analysis of the morning samples. However, it should be noted that this was a very small study of 11 men and 12 women. The meta-analysis by Chida and Steptoe (2009) provided some further evidence for the inverse association between positive affective states or traits and the cortisol awakening response, but only under particular circumstances. Out of the 12 studies in their meta-analysis, the overall relationship between measures of positive wellbeing and CAR was not significant. However, when the meta-analysis only included studies using particular techniques for calculating the CAR (area of cortisol increase under the curve or AUCi, and mean post awakening value minus waking value or MINC), there was a significant inverse association between positive wellbeing and CAR. Likewise for studies with 3 or more cortisol samples included in their awakening response calculations.

In summary, the cortisol and positive wellbeing studies appear to have conflicting results. Some studies reported inverse associations between positive wellbeing and the CAR but not for cortisol during the rest of the day, others found inverse associations for diurnal cortisol but not the CAR, and yet others found significant inverse associations for both diurnal and morning cortisol. One of the reasons for the disparity in findings may be because different studies used different methods to calculate diurnal cortisol or CAR. Additionally, each study used a different measurement of positive wellbeing. However, where results are significant, it seems lower cortisol levels are found in people with greater positive wellbeing. This may imply a potential protective effect of positive wellbeing on health via its association with reduced cortisol. Efficient cortisol regulation may reduce the risk of the metabolic and inflammatory diseases associated with high cortisol levels.

1.4.3 Heart rate

The sinoatrial node, which controls heart rate (HR, measured in beats per minute), is under partial control from the sympathetic and parasympathetic nervous systems. As mentioned earlier, sympathetic influence increases HR, whereas parasympathetic influence (primarily controlled by the vagus nerve) reduces HR. Input from both systems vary as part of a dynamic, antagonistic relationship that has an overall combined effect on HR (Thayer, et al., 2010). Continuously raised HR is associated with increased blood pressure, which may lead to hypertension, a factor related to increased risk of CHD (Palatini & Julius, 1997).

The majority of studies examining positive wellbeing and HR are laboratory-based mood induction experiments. Most of these studies suggest increased HR during positive emotional states (for a review see Boehm & Kubzansky, 2012; Pressman & Cohen, 2005). Heart rate response to emotional arousal is thought to correspond to level of arousal rather than valence, therefore an increase in HR can also be observed during negative emotional arousal. However, the heart rate response tends to be greater in magnitude and lasts longer for negative emotions such as anger and fear compared with positive emotions (Brosschot & Thayer, 2003; Ekman, Levenson, & Friesen, 1983).

Studies of dispositional wellbeing (rather than induced positive mood states) and cardiovascular recovery may be more health relevant, as faster recovery implies a reduced duration of rapid HR. Cardiac recovery was found to be faster in healthy people with higher levels of trait positive wellbeing after negative emotional arousal (Tugade & Fredrickson, 2004). However, in laboratory stress tests, positive affect was not associated with heart rate at any time point including baseline, reactivity or recovery from stress (Bostock, Hamer, Wawrzyniak, Mitchell, & Steptoe, 2011; Steptoe, et al., 2007). This was according to two measures of positive affect; the Positive and Negative Affect Schedule (PANAS, Watson, Clark, & Tellegen, 1988) and EMA. In addition, Steptoe et al (2005) found no difference across the happiness quintiles according to heart rate recovery following stress. It seems that significant associations between positive affect and cardiac recovery may be limited, although it is difficult to make a judgement in this area until more evidence has been collected.

Naturalistic assessments of affective states and heart rate can avoid some of the problems associated with laboratory-based paradigms (such as reduced ecological validity) and are the most relevant to everyday cardiovascular regulation and therefore health. Daly, Delaney, Doran, Harmon and MacLachlan (2010b), found that daily negative affect was associated with increased HR. Steptoe et al (2005) and Steptoe and Wardle (2005), reported that greater happiness ratings were associated with decreased HR in men but not women. However, a number of ambulatory studies found no association between heart rate and positive mood (e.g. Jacob et al., 1999; Shapiro, Jamner, & Goldstein, 1997; Shapiro, Jamner, Goldstein, & Delfino, 2001). It should be noted that both Jacob et al (1999) and Shapiro et al (1997) also found no association between HR and negative affect.

The disparity in findings here may be attributable to methodological differences. For example, Jacob et al (1999) and Shapiro et al (1997) only measured the presence or absence of mood states and did not include mood intensity in their analyses. Shapiro et al (2001) did include intensity of happiness ratings averaged across the monitoring period in their analyses similarly to Steptoe et al (2005). However, the treatment of the happiness ratings in these latter two studies differed. Steptoe et al (2005) calculated percentage of happiness ratings of 4 or 5 across the day (from an initial scale of 1 to 5, with 5 indicating the highest levels), whereas Shapiro et al (2001) used the mean ratings as reported by the participants (from 1 to 5).

Overall, there appears to be limited evidence for associations between ambulatory HR and positive wellbeing in naturalistic studies in women, but there were a few significant findings in men. Reasons for the gender differences are unclear, although it has been suggested that the neural control of heart rate in women may be different (more complex) than in men (Kuo et al., 1999; Ryan, Goldberger, Pincus, Mietus, & Lipsitz, 1994). One possibility for the lack of association between positive affect and heart rate in several ambulatory studies could be that positive emotional episodes experienced in daily life may not be strong enough (in terms of arousal levels) to have a significant impact on heart rate. Laboratory-induced positive mood states can be manipulated to produce stronger mood responses and therefore may be able to demonstrate associations with heart rate more consistently. Also, as described earlier, heart rate responses to negative emotions are greater and last longer than during positive emotional states.

1.4.4 Heart rate variability

Heart rate variability (HRV) is a measure of the short term variability over time of the beat to beat interval (or R-R interval, see Figure 1.4), and can be used to assess the autonomic regulation of cardiac function, reflecting the balance between sympathetic and parasympathetic nervous system control (Task Force, 1996). HRV can be affected by intrinsic factors including genetic variability and cardiovascular disease (CVD), as well as external influences, both psychological (such as stress) and physiological (such as level of activity). Thus, HRV can be used as an objective measure of the physical effects of behavioural factors on the body, as well as a diagnostic tool for ascertaining cardiac health (Rajendra Acharya, Paul Joseph, Kannathal, Lim, & Suri, 2006).

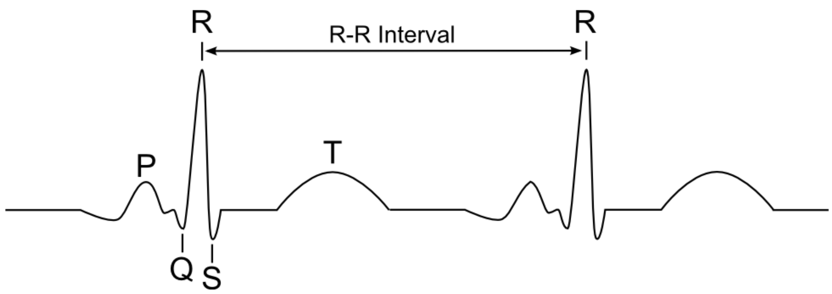


Figure 1.4: An idealised electrocardiogram (ECG) section of a healthy person (from Burke, 2007, with permission)

There are a number of different methods of measuring HRV, including frequency measures and time-domain measures calculated from differences between successive R-R intervals, e.g. root mean successive standard deviation (or RMSSD, which is thought to be related to parasympathetic nervous control of the heart). The frequency measures correspond to the amount of HRV occurring at different frequencies and are calculated from the electrocardiogram (ECG) using power spectral analysis (as shown in Figure 1.5). High frequency HRV (HF-HRV) in the range 0.15-0.40 Hz is generally taken to reflect parasympathetic control (e.g. Berntson, Cacioppo, & Quigley, 1993; Cacioppo et al., 1994), whereas low frequency (LF-HRV) activity in the 0.04-0.15 Hz band and the LF/HF ratio are thought to be indicators of sympathetic/ parasympathetic balance (Malliani, Pagani, Lombardi, & Cerutti, 1991; Pagani et al., 1986). However, the interpretation of the LF/HF ratio is controversial (Pomeranz et al., 1985; Thayer, et al., 2010).

1.4.4.1 HRV, stress and health

High levels of stress tend to be associated with increased sympathetic and/or decreased parasympathetic control, so lead to changes in HRV. An increase in heart rate and LF-HRV and decrease in HF and/or increase in LF/HF ratio have been found in many laboratory and naturalistic acute stress studies (for a review see Berntson & Cacioppo, 2007). Similarly, chronic work stress has been associated with increased heart rate and reduced HRV in both men and women, as seen by reduced HF and increased LF/HF ratio in men (Clays et al., 2011), increased LF/HF ratio and reduced time domain measures of HRV in women (Hintsanen et al., 2007), and reduced HF and LF components in both sexes (Chandola et al., 2008).

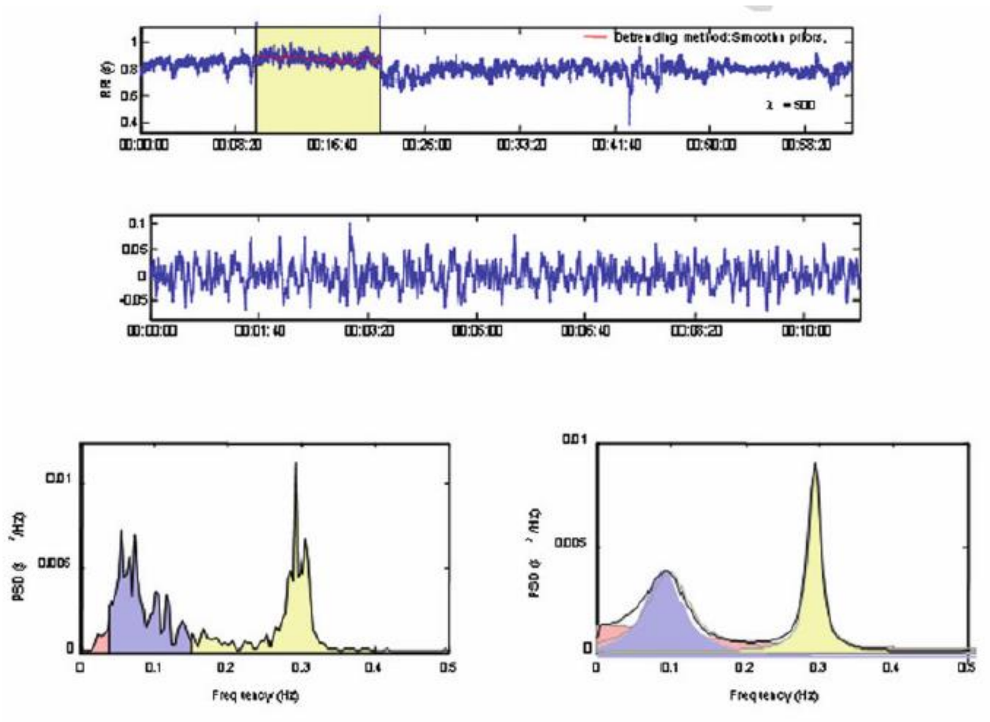


Figure 1.5: Plotting frequency measures of heart rate variability (from Thayer, et al., 2010, pp 729, with permission).

The figure shows R-R intervals plotted over time (top), with a close-up of the shaded portion (middle). Raw frequency plot (bottom left), and averaged frequency plot (bottom right) following power spectral analysis of R-R intervals. The peak on the right (yellow) represents higher frequencies and the blue peak on the left, lower frequencies, in the bottom graphs

There are, however, some discrepancies in this area as a smaller study of 159 young female nurses reported no association between work stress and HRV (Riese, Van Doornen, Houtman, & De Geus, 2004). Also, a study of work stress and RMSSD measures of HRV found that the relationship between increased work stress and reduced HRV was only significant in workers aged 35-44, but not in younger or older age groups (Loerbroks et al., 2010). It should be noted, however, that the latter study included only a small number of female participants (N= 71). Because Chandola et al (2008) and Hintsanen et al (2007) included much larger samples of women (6895 and 457 respectively), they are likely to be more indicative of the work stress-HRV link in women compared with Riese et al and Loerbroks et al.

Autonomic imbalance, indicated by reduced HRV and a dominance of sympathetic relative to parasympathetic activity, has been associated with a number of health problems thought to be caused by structural and functional changes to the cardiovascular and metabolic systems (Thayer & Lane, 2007). Reduced HRV has been associated with increased risk for cardiac events and cardiovascular disease among the general population (Dekker et al., 2000; Tsuji et al., 1996), following myocardial infarction (La Rovere & Bigger, 1998) and in patients with diabetes (Liao, Carnethon, Evans, Cascio, & Heiss, 2002). Reduced vagal tone (i.e. reduced parasympathetic activity) has also been linked to several risk factors for CVD including hypertension, obesity and cholesterol (Thayer & Lane, 2007).

1.4.4.2 HRV and positive wellbeing

Research on positive attributes and measures of cardiac function has suggested that greater positive wellbeing may be associated with increased HRV, though the evidence is modest. For example, higher positive affect has been associated with greater HF-HRV in patients with suspected coronary artery disease (Bhattacharyya, et al., 2008), and with increased LF-HRV in patients with documented coronary artery disease (Bacon et al., 2004). Geisler, Vennewald, Kubiak and Weber (2010) found an association between increased HF-HRV and cheerfulness and life satisfaction in a student sample. However, there was no association between momentary happiness and HRV assessed with ambulatory monitors in a study of female students (Myrtek, Aschenbrenner, & Brügner, 2005).

There may be differences between momentary and trait measures of positive wellbeing in relation to HRV. This notion is further complicated by evidence from Papousek and colleagues (2010), who report an inverse association between trait positive affect and LF/HF ratio during recovery from an academic stressor, but a positive relationship between *state* positive affect prior to the stressor and LF/HF ratio post-stressor (suggesting prolonged recovery). Because state measures are taken concurrently with biological assessment, and positive states with high arousal/activation can be associated with increased heart rate and SNS activity, this may explain these unexpected findings.

A recent study adds weight to this idea. EMA measures of positive affect with high activation (e.g. feeling awake) were negatively associated with vagal tone (i.e. with reduced parasympathetic activity), whereas measures with low activation (e.g. feeling calm) were positively associated with vagal tone (Schwerdtfeger & Gerteis, 2014). However, aggregated measures of high activation positive affect over the 3 day monitoring period were related to greater vagal tone. Positive affective experience over time may therefore have a different influence on cardiac regulation compared with momentary affect.

The studies of positive wellbeing and HRV in healthy participants are difficult to compare since each study uses a different measure of positive wellbeing and either static/resting (Geisler, et al., 2010), momentary (Myrtek, et al., 2005; Schwerdtfeger & Gerteis, 2014) or post-stress recovery measures of HRV (Papousek, et al., 2010). Also, Geisler et al (2010), use trait HRV as a predictor of positive wellbeing rather than positive traits predicting HRV (the latter of which is more common in this area of research). This also suggests there could be a bidirectional relationship between affect and measures of cardiac autonomic control.

Indeed, Kok and Fredrickson (2010), suggest that positive emotions and vagal tone are both prospectively and reciprocally associated with each other. In this study, resting vagal tone was measured at baseline and after a 9 week study. During the study, participants were asked to give daily ratings of emotions and to assess daily social interactions. Kok and Fredrickson reported that greater baseline vagal tone predicted increases in social connectedness and daily positive emotion across the 9 weeks. This increase in social connectedness and positive emotions predicted greater end of study vagal tone, independently of vagal tone at the start. Kok and Fredrickson argue that the interaction between vagal tone and positive emotions work by creating an ‘upward spiral’ whereby greater autonomic flexibility moderates daily positive emotions, and consequently, increases in daily positive emotions have a beneficial effect on improving vagal tone.

1.4.5 Blood pressure

The SNS controls the constriction of arteries and veins throughout the body and is under the influence of the hypothalamus, which regulates the vasomotor centre in the brainstem responsible for keeping blood pressure at an appropriate level. Increased SNS activity constricts blood vessels leading to increased blood pressure, whereas the inhibition of SNS activity dilates blood vessels (reduces blood pressure). Baroreceptors (stretch receptors) in the artery walls and heart tissue respond to changes in blood pressure and send signals to the vasomotor centre which adjusts the control of heart rate accordingly. Heart rate and blood pressure are normally inversely related (via the baroreceptor reflex) but can both increase under certain circumstances such as during exercise and following negative emotional arousal (Andreassi, 2007; Steptoe, 1980).

Blood pressure is measured using a sphygmomanometer consisting of an inflatable cuff and a monitor which receives information on blood pressure as the cuff deflates. Blood pressure readings are given for systolic blood pressure (maximum pressure during heart muscle contraction) and diastolic blood pressure (minimum pressure during heart muscle relaxation). Blood pressure is highly variable during the day but is usually low on waking and rises throughout the day, typically reaching a peak around the late afternoon/early evening, with lowest levels during sleep. Normal resting blood pressure for adults ranges from 95 to 140mmHg with an average of 120mmHg for systolic blood pressure, and 60 to 85mmHg with an average of around 80mmHg for diastolic blood pressure. Hypertension is defined as consistent readings of blood pressure at or above 140mmHg systolic and 90mmHg diastolic. Hypertension is a major risk factor for CVD and is implicated in chronic kidney disease (Chobanian et al., 2003).

As in heart rate, the majority of studies investigating positive wellbeing and blood pressure have involved laboratory-based mood induction and report increased blood pressure during positive states. Similarly, the magnitude and duration of the increase in blood pressure during positive states tend to be less than during negative emotions, especially anger and fear, which elicit the greatest responses (for a review, see Pressman & Cohen, 2005). Blood pressure response is also closely linked to the level of emotional arousal rather than valence, as in the heart rate response (Jacob, et al., 1999; James, Yee, Harshfield, Blank, & Pickering, 1986).

In laboratory studies of trait positive affect (rather than induced mood) and cardiovascular reactivity and recovery following stress tests, mixed results have been found depending on the measure of positive affect. For example, Steptoe et al (2007) reported associations between higher trait positive affect and lower diastolic blood pressure at baseline and faster recovery after stress tests, according to EMA but not

PANAS measures. Systolic blood pressure was inversely associated with positive affect overall (but not with reactivity and recovery from stress) according to both measures of positive affect. In a study of women only, Bostock et al (2011) found an association between positive emotional style (or PES, a measure of positive affect similar to PANAS) and faster recovery for diastolic blood pressure, but no significant results for systolic blood pressure.

Similar to mood induction studies, naturalistic ambulatory studies have found positive associations between blood pressure and concurrent ratings of positive affect (e.g. Gellman et al., 1990; Jacob, et al., 1999; Shapiro, et al., 1997). However, other naturalistic ambulatory studies report no association between blood pressure and positive affect (e.g. James, et al., 1986; Steptoe, et al., 2005). Perhaps the results are less consistent here because the level of arousal during positive emotional episodes in naturalistic studies may not be as high as in laboratory studies where stronger emotional states may be elicited following experimental manipulation.

So far most of the research in this area has been cross-sectional and has examined momentary positive states. It may be that the relationship between positive wellbeing and blood pressure changes over time, or that the relationship differs with age. In a longitudinal study of middle aged men and women, Steptoe and Wardle (2005) reported no association between EMA measures of positive affect and blood pressure at baseline, but found an inverse association between positive affect and systolic blood pressure 3 years later in the same participants. They suggest the difference in finding may be due to advancing age.

A large epidemiological study of 2564 elderly Mexican Americans found that resting blood pressure was inversely related to positive affect from the CES-D scale (Ostir, Berges, Markides, & Ottenbacher, 2006). Higher trait optimism has been associated with lower ambulatory systolic and diastolic blood pressure (measured across 3 days) in 30 to 45 year old participants (Räikkönen, Matthews, Flory, Owens, & Gump, 1999). However there was no association between a single item measure of optimism and hypertension risk in middle-aged participants, although people with higher emotional vitality had a reduced risk of hypertension (Trudel-Fitzgerald, Boehm, Kivimaki, & Kubzansky, 2014). Thus, it may be that global measures of wellbeing, rather than momentary or state measures, are more closely related to blood pressure and that the relationship may be more apparent in mid to older age.

1.4.6 Overcoming methodological issues

Overall, the relationships between positive wellbeing and health related biological correlates were fairly mixed. Some studies reported associations between positive states or traits and biology, whereas others reported null findings. Possible reasons for these disparities include differences in methodology (especially measures of positive wellbeing), participant number and type, and study design. Where significant findings have been reported, the overall direction of results suggests that greater positive wellbeing is associated with levels of biological correlates thought to be health protective. For example, greater positive wellbeing has been linked to lower levels of cortisol and to greater HRV. There may be gender differences for some of these relationships e.g. some reported associations between positive wellbeing and heart rate were found in men only.

The findings for blood pressure and heart rate were particularly inconsistent. There were reports of inverse associations, positive associations or non-significant results for the relationships between blood pressure, heart rate and positive wellbeing. Perhaps this inconsistency was because concurrent emotional arousal tends to be associated with increases in blood pressure and heart rate; whether positive or negative, so level of arousal may be the most important factor here. Some global measures of positive wellbeing were inversely related to blood pressure, but there was limited evidence for associations between heart rate and wellbeing in naturalistic studies, particularly in women.

The lack of consistency between study results makes comparisons among the various findings difficult. Studies in this area are sparse and heterogeneous. It would be useful to clarify associations between health-related biological correlates and at least one positive characteristic using a group of similar participants. A relatively homogeneous participant base would help to reduce the number of confounding factors which could potentially affect the positive wellbeing and biology links, such as gender. Additionally, assessing biological correlates such as cortisol via different methods within the same participants may help to clarify whether inconsistencies in findings are due to differences in biological assessment.

The studies presented in this thesis aim to address some of these issues. For example, I investigated resilience and biology using the Daytracker study which had a large sample of healthy women with similar demographic characteristics. Cortisol was measured across two days: a work day and a leisure day (to account for possible differences between the two days). Three different measures of cortisol were calculated: CAR, total cortisol (area under the curve) and cortisol slope (see Chapter 5). Heart rate and HRV were also assessed across a work and leisure day using frequency measures of HRV to allow the relative contribution of sympathetic and parasympathetic nervous influence to be estimated (see Chapter 6). In the resilience studies, I was able to reduce the influence of individual demographic differences as much as possible by using a relatively homogenous participant sample. Also, I was able to factor out the possibility that inconsistencies between studies may be caused by using different psychological measures by focussing on one factor, resilience.

Another issue to consider here is that the studies presented in section 1.4 provide evidence for *associations* between positive wellbeing and biological correlates but they cannot establish causality. Chapter 9 therefore presents an intervention study which aims to demonstrate causal mechanisms between changes in positive wellbeing and changes in health-related biological correlates. Similar to the resilience studies, the three measures of cortisol (CAR, total cortisol and cortisol slope) were assessed and heart rate and blood pressure were used as measures of cardiovascular function.

1.5 Positive wellbeing and health protective behavioural factors

There appears to be some evidence for a link between affective states or traits and biological measures relating to health. However, there are many factors that may influence positive wellbeing, including genetics, personality traits and socioeconomic elements. Some of these factors are themselves linked to positive health outcomes, and so could provide *indirect* pathways for the influence of positive wellbeing on health. Health behaviours such as exercise have been linked to both positive wellbeing and beneficial effects on health. Hence they may also provide indirect pathways between positive wellbeing and health (see Figure 1.1).

There are numerous benefits associated with improved health behaviours such as a healthy diet, regular exercise and not smoking. For example, smoking has been well-established as a risk factor for CVD (among many other diseases), whereas people who exercise regularly are at reduced risk of CVD along with various types of cancer, and inflammatory diseases (Centers for Disease Control and Prevention 1996; Thompson, 2002). Greater positive wellbeing has been associated with increased likelihood of adopting a number of health protective behaviours; examples relevant to this thesis are given below.

1.5.1 Physical activity

Physical activity has been associated with improved mood, increased self-esteem, and better general and health related quality of life (Penedo & Dahn, 2005; Scully, Kremer, Meade, Graham, & Dudgeon, 1998). Physical activity has also been found to alleviate the symptoms of depression, anxiety and improve recovery from stress. Consequently, interventions designed to increase physical activity have shown marked improvements in physical and mental wellbeing (Conn, 2010; Stathopoulou, Powers, Berry, Smits, & Otto, 2006; Steptoe, 2006). Most longitudinal investigations of positive wellbeing and physical activity have assessed changes to wellbeing following activity, rather than the other way round. Thus, the causal relationship between positive wellbeing and physical activity is not yet clear, although it is likely to be bidirectional (Penedo & Dahn, 2005).

Cross-sectional studies have consistently reported associations between greater wellbeing and a higher incidence of taking regular exercise. For example, in a very large telephone survey of over 350 000 US citizens, higher life satisfaction (from a single item measure) was associated with reduced incidence of physical inactivity, defined as no activity within the last 30 days (Strine, Chapman, Balluz, Moriarty, & Mokdad, 2008). In another larger study of 17 000 participants across 21 countries, greater life satisfaction scores were associated with increased likelihood to exercise regularly (Grant, Wardle, & Steptoe, 2009). Nabi et al (2008a) also reported that people with higher positive affect were more likely to exercise for 1.5 hours or more per week. Similarly, people with a more optimistic outlook tend to take regular exercise (Boehm, Williams, Rimm, Ryff, & Kubzansky, 2013; Giltay, Geleijnse, Zitman, Buijsse, & Kromhout, 2007; Steptoe, Wright, Kunz-Ebrecht, & Iliffe, 2006).

1.5.2 Smoking

The majority of studies assessing positive wellbeing and smoking status suggest that positive wellbeing is higher in non-smokers compared with smokers. Higher life satisfaction was associated with reduced likelihood of smoking in university students around the world and in American citizens (Grant, et al., 2009; Patterson, Lerman, Kaufmann, Neuner, & Audrain-McGovern, 2004; Strine, et al., 2008). Smoking status also differs according to optimism: non-smokers tend to have higher optimism scores (Boehm, et al., 2013; Giltay, et al., 2007; Kelloniemi, Ek, & Laitinen, 2005; Steptoe, et al., 2006). In studies assessing positive affect, Davidson et al (2010) found an inverse association between positive affect and smoking prevalence. The studies mentioned here only examine cross-sectional associations between smoking and positive wellbeing. Therefore it is not possible to say whether people with higher levels of positive affect are less likely to smoke in the future (or vice versa).

Overall, there seems to be a connection between positive wellbeing and adopting health beneficial behaviours. The influence of physical activity is addressed in the study on resilience and HRV, since physical activity is related to positive wellbeing, cardiac regulation and health. Additionally, some statistical models have been adjusted for smoking status in this thesis since smoking may influence biology (although it should be noted that it is also related to health and positive wellbeing). As the focus of this thesis is the connection between positive wellbeing and biology, the role of health behaviour is acknowledged, but has not been investigated extensively.

1.6 Thesis structure and overall aims

The first part of this thesis (Chapters 2 to 7) explores associations between resilience (as an example of a positive trait) and a number of biological and psychological factors. The second part (Chapters 8 and 9) presents an intervention study to directly investigate causal mechanisms between positive wellbeing and biological correlates of health. Thus, two important areas in positive wellbeing (personality and intentional activities) are explored. By using two related approaches to studying positive wellbeing and biology, I aim to provide evidence for the notion that positive wellbeing provides health protective benefits via psycho-biological mechanisms. I will do this by: 1) clarifying associations between resilience (as an example of a positive personality trait) and measures of biological and psychological factors relevant to health, and 2) attempting to demonstrate causal pathways between changes in positive wellbeing and changes to biology.

2 Resilience as an example of a positive personality trait

Chapter 1 outlined research on positive wellbeing and how it may be health protective. The next four chapters investigate resilience as an example of a positive personality trait, which may also be health beneficial. This section of the thesis aims to expand knowledge on interrelationships between resilience and various health related outcomes in areas that have received little previous exploration.

In this chapter, the theoretical underpinnings for the analyses in the resilience chapters (4 to 6) are explained. Data for these analyses came from the Daytracker study. This was a large, cross-sectional study of healthy working women which assessed resilience, as well as a number of other psychological, demographic and biological factors (detailed in Chapter 3).

Resilience was chosen as a focus because it is a central psychological concept in understanding why some people are resistant to stress and adapt effectively to adverse conditions. It is relevant to positive wellbeing and health as well as stress (as will be explained further in this chapter) and therefore can be used to examine links between all 3 areas. Since many of the biological correlates of health outlined in Chapter 1 are also correlates of stress, it follows that resilience (as the ability to withstand stress) may also be associated with these biological factors.

The field of resilience and mental wellbeing is relatively well established, whereas there is little consistent evidence for links between resilience and physical health. Furthermore, even less is known about resilience and the biological correlates of health. The concept of resilience and what is known about the associations between resilience, positive wellbeing, stress and mental and physical health are reviewed in this chapter.

2.1 The concept of resilience

Early resilience research originated in a developmental context, following investigations into the capacity of children to thrive despite being exposed to significant levels of adversity (Rutter, 1987). The personality trait of 'hardiness' has been suggested as the prototype for the more modern concept of resilience. Hardiness is described as a personality trait (characterised by a high level of commitment, a sense of control and the perception of stressful events as a challenge rather than a threat), which helps protect against illness under periods of stress (Kobasa, 1979). Following the original concept of hardiness, several researchers perceived resilience as an innate set of personality characteristics that were fairly stable over time, e.g. Block and Kremen's (1996) concept of ego-resiliency. Others suggest that resilience is most relevant to adaptation to infrequent or isolated adverse events, such as trauma following disaster (e.g. Bonanno, Galea, Bucciarelli, & Vlahov, 2007). From the psychiatric and biological perspective, the emphasis is on the avoidance of mental illness or maladaptive processes and tends to focus on outcomes related to adaptation to adversity, rather than the process/development of resilience itself.

Because resilience is studied in different areas of psychology, from developmental psychology to communities and psychiatric studies, there is considerable variability in the definition, conceptualisation and operationalisation of resilience within each area. Indeed, this is one of the major criticisms of the field (Kaplan, 1999; Luthar, Cicchetti, & Becker, 2000). In an effort to address this problem, Windle (2011) conducted an extensive review of resilience definitions and suggests the following:

> *Resilience is the process of effectively negotiating, adapting to or managing significant sources of stress or trauma. Assets and resources within the individual,*

> *their life and environment facilitate this capacity for adaptation and 'bouncing back' in the face of adversity. Across the life course, the experience of resilience will vary.* (p163)

Windle's quote sets resilience as a process which evolves throughout life, as this definition is taken from a developmental perspective. However, most assessments of resilience treat it as a multidimensional personality trait since resilient individuals are thought to use a range of positive traits, cognitive processes and external resources in order to adapt to adversity. For example, many conceptualisations of resilience include personality characteristics, such as self-efficacy and having a positive outlook on life, mental abilities such as cognitive flexibility and learning from past experience, as well as the role of external factors such as social support. As resilience is multifaceted, it overlaps with a number of other psychological constructs such as coping and optimism.

People with high resilience are not only characterised by being able to 'get through' stressful periods, but are also able to function above the level expected under difficult or stressful situations (Davydov, Stewart, Ritchie, & Chaudieu, 2010). As the assessment of resilience includes evaluating past coping behaviour, it therefore partially relies on prior exposure to stressful events (Ong, Bergeman, & Boker, 2009). Whether or not resilience is termed as a largely fixed personality trait, or is part of a process that develops over time, is a matter for debate (Jacelon, 1997). According to Windle's definition, it is most likely that the concept of resilience combines innate personality characteristics with elements that could change according to experience and with exposure to stressful events.

While resilience could be a process, for the purposes of the studies presented in the following chapters, resilience is treated as a fixed personality trait. This is because the design was cross-sectional and the scale used in the study was developed as a measure of dispositional resilience. It is not possible to measure a process with a cross-sectional design. However it should be noted that resilience may change to a certain extent over the life course. For example, there is some evidence to suggest that resilience increases with age (Lundman, Strandberg, Eisemann, Gustafson, & Brulin, 2007; Portzky, Wagnild, De Bacquer, & Audenaert, 2010). This fits the idea that resilience is partly dependent on previous exposure to stressful events, since there may be a cumulative effect of the experience of a greater number of adverse events and/or the development of appropriate coping responses with age.

Aside from age, other demographic and socioeconomic factors may contribute to resilience. Links between higher resilience and social factors such as having a partner (Beutel, Glaesmer, Wiltink, Marian, & Brähler, 2010) and greater social support (Nishi, Uehara, Kondo, & Matsuoka, 2010) have been suggested. Higher income (Beutel, et al., 2010; DeNisco, 2011; Perna et al., 2011) and level of education (Perna, et al., 2011; Portzky, et al., 2010) have also been associated with greater resilience. However, not all studies report associations between resilience and education (e.g. Chedraui et al., 2012; DeNisco, 2011; Pinquart, 2009). Thus, resilience may differ according to availability of external resources, although relationships may vary according to different populations and resource measures. This suggests that resilience should not be considered in isolation but alongside relevant socioeconomic factors. The relationship between resilience and several demographic and socioeconomic factors have been considered in the analyses from the Daytracker study.

2.1.1 Measuring resilience

Resilience has been assessed in adults in a variety of different populations and situations, particularly in the context of the development of disorders such as post-traumatic stress disorder (PTSD) and depression (Charney, 2004). Unfortunately, there has been a tendency to define resilience by a lack of stress response or symptoms rather than measuring it directly as a psychological construct. There is a danger of circular reasoning, with the level or type of stress response being used to characterise resilience, which is then evoked as the explanation for the attenuated stress responses. Studies of resilience therefore benefit from the direct measurement of resilience.

There are a number of resilience scales available; a review of these scales by Windle and colleagues (2011), counts around 15 different scales as of 2009. Commonly used scales include the the Resilience Scale (Wagnild & Young, 1993), the Connor-Davidson Resilience Scale (CD-RISC, Connor & Davidson, 2003) and the Ego-Resilience scale (Block & Kremen, 1996). These measures vary quite substantially according to their theoretical basis and application. Each scale assesses resilience from a slightly different perspective and many have been developed from distinct conceptual backgrounds. Therefore when conceptualising resilience within a study population, we must also consider the method of measurement.

The Daytracker study used the Resilience Scale (Wagnild & Young, 1993) to measure dispositional resilience and its associations with objective physiological and self-report measures. The Resilience Scale was developed following a qualitative study involving 24 older age women to explore aspects of how they had adapted successfully after a major life event (Wagnild & Young, 1990). Fifty verbatim statements were taken from the participants when asked how they had coped with a self-identified loss (such as the loss of a spouse), which were then analysed and reduced to 25 items. A further shorter version of the scale consisting of 14 items was also developed (as used in the Daytracker study). According to Wagnild and Young (1990), these items were thought to reflect five characteristics of resilience; i) perseverance or persistence (the ability to keep going despite adversity), ii) equanimity (a balanced outlook on life), iii) meaningfulness (that there is a purpose to life), iv) self-reliance, and v) existential aloneness (a sense of uniqueness and in the context of the fact that some experiences have to be faced by oneself).

Thus, resilience as measured using the Resilience Scale can be viewed as a multi-faceted construct, which includes both personality traits and factors relating to past circumstances. This can be seen more clearly when considering specific items of the scale. For example, 'I have self-discipline' is more likely to be personality related, whereas 'When I am in a difficult situation, I can usually find my way out of it' relies partly on having been through difficult situations and could potentially improve with experience. Despite including both personality-related and experience-related measures, the Resilience Scale is often regarded, and treated, as a trait measure.

In comparison to the Resilience Scale, other measures of resilience have a different conceptual basis. For example, the CD-RISC was developed for clinical use to measure ability to cope with stress and includes factors such as personal competence, ability to withstand negative affect, and acceptance of change (Connor & Davidson, 2003). The Ego-Resilience scale presents resilience as a stable personality trait which does not depend on exposure to adversity and pre-disposes an individual to be able to tolerate stress (Block & Kremen, 1996). Despite the differences and individual merits of each scale (discussed further in Chapter 7), all resilience measurements share the common goal of assessing ability to cope with stress or adversity. Additionally, some measures of resilience assess aspects of positive wellbeing such as optimism and life meaning since positive factors are thought to play an important part in the concept of resilience.

2.2 Resilience and positive wellbeing

Positive correlations have been reported between resilience and subjective wellbeing, including positive affect and satisfaction with life (Beutel, et al., 2010; Burns & Anstey, 2010; Burns, Anstey, & Windsor, 2011; Christopher & Kulig, 2000; Cohn, et al., 2009; Jung et al., 2012; Mak, Ng, & Wong, 2011; Smith et al., 2008; Wagnild & Young, 1993). Measures of eudaimonic wellbeing such as purpose in life and psychological wellbeing are also positively associated with resilience (Alessandri, Vecchione, Caprara, & Letzring, 2012; Jung, et al., 2012; Min et al., 2013; Nygren et al., 2005; Smith et al., 2009). Additionally, resilient individuals tend to score highly in measures of other beneficial characteristics such as optimism (Lamond et al., 2008; Min, et al., 2013; Petros, Opacka-Juffry, & Huber, 2013; Smith, et al., 2008; Smith, et al., 2009) and self-esteem (Baek, Lee, Joo, Lee, & Choi, 2010; Beutel, et al., 2010; Mak, et al., 2011). Thus, people with high levels of resilience tend to enjoy greater positive wellbeing.

As mentioned earlier, there is considerable conceptual overlap between resilience and other positive traits. Therefore correlations between resilience and measures of positive wellbeing are often used to validate scales during development, rather than to explore mental wellbeing *per se,* since there would be a danger of circular reasoning. As resilience scales include positive characteristics as part of their measurement, associations with similar traits are to be expected. However, this does not mean that resilience is redundant. Despite strong correlations between resilience and affect, resilience was found in at least one study to be independent of trait positive and negative affect (Burns & Anstey, 2010). This suggests that resilience assesses something unique.

The extent to which other positive traits are predictive of resilience (or vice versa) is unclear since the majority of studies in this area are cross-sectional. There is, however, some evidence for a bidirectional relationship between state positive wellbeing and resilience. Theoretical models have implicated the role of positive emotions both in building resilience and in the process of dealing with stress and adversity (Fredrickson, 2004; Mancini & Bonanno, 2009; Tugade & Fredrickson, 2004). In Fredrickson's (2004) Broaden and Build theory (see Chapter 1, section 1.2) positive emotions contribute to building some of the resources necessary for resilience e.g. cognitive flexibility, coping skills and social support. Resilient people then use positive emotions to help bounce back from stress or adversity (Fredrickson, Tugade, Waugh, & Larkin, 2003; Tugade & Fredrickson, 2004). The active use of positive emotions during adversity is thought to further strengthen resilience in the long term by increasing ability to cope with future stressful experiences (Tugade, Fredrickson, & Barrett, 2004). In other words positive emotions both contribute to and are determined by individual differences in resilience. Positive emotions are also proposed to help resilience in the face of adversity by dampening the impact of negative states on wellbeing (Tugade, et al., 2004).

Resilient individuals still experience negative affect and may initially respond to adversity in a similar way to people with low resilience, but they report experiencing greater amounts of positive emotions at the same time (Mancini & Bonanno, 2009). For example, a rare prospective study by Fredrickson et al (2003) allowed investigation of the influence of resilience measured prior to the 9-11 terrorist attacks in New York on post-crisis adaptation. They found that although students with higher resilience experienced negative emotions (e.g. anger and sadness) following 9-11, they reported greater experiences of positive emotions (namely gratitude, interest and love) compared with less resilient students. Increases in optimism, subjective wellbeing and tranquillity after the crisis were found in people with higher trait resilience, indicating post-crisis growth. Additionally, the relationship between resilience and post-crisis growth was fully mediated by positive emotions, which further suggests the importance of positive emotions in the process of resilience.

2.3 Resilience, stress and allostasis

Several studies report that resilience has an inverse relationship with measures of perceived stress in the general population (Ahern & Norris, 2011; Baek, et al., 2010; Hjemdal, Friborg, Martinussen, & Rosenvinge, 2001; Jung, et al., 2012; Smith, et al., 2008; Wagnild & Young, 1993), in patient samples (Connor & Davidson, 2003; Jung, et al., 2012; Smith, et al., 2008) and in specific populations such as carers of people with Alzheimer's disease and military personnel (Hourani et al., 2012; Wilks, 2008). This is to be expected considering that resilience is identified as the ability to flourish under adverse or stressful conditions.

A number of issues in this area remain to be clarified. It is not clear at which stage in the stress-response process resilience is most active or relevant. It may be that resilient people show a cognitive bias towards perceiving situations to be less stressful than would otherwise be considered under the circumstances. They may even utilise behavioural or lifestyle changes to simply avoid stress in the first place. Or it may be that resilient people are able to rapidly adapt to adverse circumstances, avoiding a prolonged stress response, and are therefore less susceptible to the negative effects of stress. The next few chapters are focussed on the latter issue of susceptibility to the negative effects of stress and explore the relationship between resilience and factors related to stress and health in detail. The measurement of biological factors related to stress such as cortisol and heart rate variability, may be able to assist our understanding of how the physiological impacts of stress may differ according to resilience.

Individual differences in susceptibility and reactivity to stress are thought to be determined by genetics, cognitive factors (such as the perception of stress) and by a person's general physical health, which can itself be influenced by both genetics and behaviour/lifestyle (McEwen, 1998). The potential risk or resilience to the impacts of stress on health are explored under the concept of allostasis and allostatic load (McEwen & Stellar, 1993). Allostasis describes the adaptive physiological changes that occur in an organism following disturbances in the environment. These adaptive biological responses to stress are mediated by several bodily systems, including the activity of the autonomic nervous system and hormones such as cortisol. These mediators are inter-connected via a non-linear system and can have negative influences on physical and mental health when they are over-produced or dysregulated (Karatsoreos & McEwen, 2011).

Allostatic load describes the conditions associated with the over-exposure or dysregulation of these physiological systems which deviate from the 'normal' biological response to stress, characterised by a rise in response followed by recovery to baseline once the stressor has subsided (McEwen & Stellar, 1993). The normal stress response is thought to be prevented under different conditions of allostatic load: by the presence of repeated waves or 'hits' of multiple stressors, by a lack of adaptation to repeated stressors over time or by dysfunctional physiological responses e.g. prolonged recovery or inadequate response. An example of allostatic load is where there is over-exposure to high levels of cortisol either through repeated stressors, a lack of adaptation to the stressor and/or a lack of recovery of cortisol levels back to normal (which may occur, for example, when the negative feedback system of the HPA axis has become dysfunctional). As a result of this allostatic 'overload' there may be negative effects on health, for example an increased risk of type 2 diabetes or inflammatory diseases, as discussed in Chapter 1, section 1.4.2.1.

Despite exposure to significant stress or adversity, resilient individuals are thought to be able to avoid the negative consequences of stress on the body (Charney, 2004). Resilient individuals may use active coping skills when under stress or simply perceive stress as less threatening. This may help to diminish allostatic load by reducing the effects of repeated stressors and by promoting adaptation to stress. Thus, resilience may be characterised (in terms of allostasis) as the appropriate response and recovery from stress, including efficient physiological function. In the long term, an efficient stress response and avoidance of allostatic overload may prevent stress-related health problems (Karatoreos & McEwen, 2013; Karatsoreos & McEwen, 2011). There is some evidence to suggest that greater resilience is associated with a reduced susceptibility to mental and perhaps physical health.

2.4 Resilience and mental health

The finding that people with higher resilience have better mental health has been well established. For example, greater resilience was associated with lower levels of depression in large studies of healthy participants from around the world, including American, European, Asian and African countries (e.g. Abiola & Udofia, 2011; Alessandri, et al., 2012; Beutel, et al., 2010; Mak, et al., 2011; Nishi, et al., 2010). Similarly, greater resilience has been associated with fewer symptoms of anxiety in healthy populations (e.g. Abiola & Udofia, 2011; Beutel, et al., 2010; Burns, et al., 2011; Mealer et al., 2012).

In psychiatric patients greater resilience was associated with fewer symptoms of depression and anxiety (Min, et al., 2013; Philippe, Laventure, Beaulieu-Pelletier, Lecours, & Lekes, 2011) and better response to antidepressant treatment (Min, Lee, Lee, Lee, & Chae, 2012). Other studies involving patients with PTSD have also demonstrated associations between higher resilience and greater treatment response (Connor & Davidson, 2003). Additionally, higher resilience was predictive of recovery from PTSD both in participants receiving drug treatment and a placebo group (Davidson et al., 2012). These studies suggest that resilience could play a role in recovery from mental illness (with or without drugs).

The connection between stress and poor mental health is well documented in population studies, twin studies and psychiatric investigations (Kendler, Karkowski, & Prescott, 1999; Monroe, 2008; Turner, Wheaton, & Lloyd, 1995). A number of different factors are thought to help reduce the risk of developing stress-induced depression including positive affect and social support (Southwick, et al., 2005). Since positive emotions form an active element of resilience, it is likely that resilience may be another protective factor attenuating the impact of stress on affect and mental wellbeing (Fredrickson, et al., 2003). Feder, Nestler, and Charney (2009) theorise a mediating effect of resilience in reducing the harmful effects of stress via the utilisation of optimal coping responses. However, the exact role of resilience in attenuating the influence of stress on mental wellbeing is yet to be determined and so this is explored in the analyses in Chapter 4.

2.5 Resilience and physical health

A small number of studies have explored associations between resilience and objective measures of physical health and disease. The results of an extensive literature search in this area are presented in Table 2.1. Papers were selected only if the study: 1) was quantitative, 2) used a recognised scale for measuring resilience, 3) assessed individual resilience in adults and 4) used an objective measure of health or disease. In addition to ‘resilience’, health related search terms included (but were not limited to): chronic illness, cardiovascular disease, arthritis, cancer, respiratory disease, autoimmune disease, infectious diseases, obesity, diabetes and neurological illness.

Despite the wide selection criteria, only a limited number of studies were found. They covered a broad spectrum of different diseases and health measures and reported fairly mixed results. For example, higher resilience was associated with improved glucose regulation in diabetics, both in a cross-sectional study (DeNisco, 2011), and a resilience intervention study (Steinhardt, Mamerow, Brown, & Jolly, 2009). The Steinhardt et al (2009) study was particularly interesting as resilience and health were measured at 2 time-points, with improvements seen in a number of health measures following resilience training. However, it should be noted that: i) the increase in resilience scores from pre- to post-intervention was not significant, and ii) this was a small pilot study of 12 participants. Additionally, the analyses in the DeNisco study were fairly simplistic; they were not adjusted for relevant factors such as age. In more sophisticated analyses, the relationship between resilience and HbA1c was no longer present (Santos, Bernardo, Gabbay, Dib, & Sigulem, 2013).

Table 2.1: Resilience and objective measures of health and disease in patients and healthy participants

Authors	**Disease/health measure**	**Scale**	**Participant characteristics**	**Findings**
Patients - diabetes				
Steinhardt et al (2009)	Diabetes (intervention study)/various measures	Connor-Davidson Resilience Scale (CD-RISC)	12 African-American people (50% men), with type 2 diabetes, 43-66 yrs old (mean age 54.8 yrs)	This was a pilot study of a resilience intervention for people with diabetes. Significant reductions in glycosylated haemoglobin levels (or HbA1c, a measure used to indicate mean plasma glucose concentration), BMI, total and low-density lipoprotein (LDL) cholesterol, systolic and diastolic blood pressure were seen post-intervention. Effect sizes were moderate to large. Resilience scores increased from pre- to post-intervention, but the difference was not significant.
DeNisco et al (2011)	Diabetes/HbA1c	Resilience Scale (RS-25)	71 African-American women with type 2 diabetes, 35-85 yrs old (mean age 55 yrs)	Higher resilience was related to better glycaemic control, as seen by an inverse correlation between resilience and HbA1c.
Santos et al (2013)	Diabetes/HbA1c	Resilience Scale (RS-25)	85 adolescents & young adults, 11-22 yrs	Resilience and HbA1c were negatively correlated but resilience did not predict HbA1c in a regression with depression, anxiety and diabetes knowledge.
Patients - various				
Hallas et al (2003)	Blood pressure, heart rate & heart rate variability	Dispositional Resilience Index (DRI, Bartone et al, 1989)	22 cardiac patients undergoing Coronary Artery Bypass Graft (CABG) surgery (77% men), mean age 62 yrs	Higher pre-operative resilience was associated with reduced post-operative ambulatory systolic blood pressure (SBP) during periods of stress. Higher post-operative resilience was associated with reduced diastolic blood pressure (DBP) during lab stress tests. Resilience was not related to heart rate or heart rate variability at any time.
Zarpour & Besharat (2011)	Irritable Bowel Syndrome (IBS)	Connor-Davidson Resilience Scale (CD-RISC)	60 patients with IBS (43% men) & 104 healthy participants (37% men), 17-50 yrs old (mean age 27.9 yrs)	Although resilience scores were lower in people with IBS, compared to healthy participants, this difference was not significant.

Robottom et al (2012)	Parkinson's disease	Resilience Scale (RS-15)	83 patients with Parkinson's disease (60% men), mean age 66.3 yrs	Resilience was not correlated with disease severity, but was negatively correlated with self-assessments of disability, fatigue, somatisation and physical health related quality of life.
Ma et al (2013)	Chronic kidney disease (CKD)	Resilience Scale (RS-25)	40 participants at high risk of CKD, 50 early stage CKD patients & 60 pre-end stage renal disease (ESRD) patients	Resilience was lower in patients with pre-ESRD compared to the other groups. Resilience was also lower in patients with pre-ESRD and diabetes compared to patients with pre-ESRD without diabetes.
Dale et al (2014)	HIV/viral load & CD4+ counts	Connor-Davidson Resilience Scale (CD-RISC)	138 HIV positive women, mean age 45.7 yrs	Each unit increase in resilience score was associated with a 1.08 increase in the odds of having high medication adherence and a 0.94 decrease in the odds of having a detectable viral load (a measure used to define HIV control). There was no relationship with CD4+ count (an immune cell count used to help define the presence of AIDS).
Healthy participants				
Dolbier et al (2001)	Immune function	The Dispositional Resilience Index (DRI)	21 healthy participants (43% men), 25-60 yrs old (mean age 40.4 yrs)	Participants were selected with particularly high or low dispositional resilience (hardiness). People in the high hardiness group had stronger immune responses, as seen by greater lymphocyte proliferation following introduction of pathogens to blood samples taken under non-stressful conditions.
Wells et al (2011)	Physical function	Resilience Scale (RS-14)	54 nuns, 55-94 yrs old (mean age 72.5 yrs)	Higher resilience was positively related to fast gait speed (an objective measure of walking ability). Performance on the Short Physical Performance Battery (an objective measure of mobility disability) was not related to resilience.
Stewart-Knox et al (2012)	Waist circumference & BMI	Resilience Scale (RS-11)	1182 British participants (51% men) & 540 Portuguese participants (47% men), 43-93 yrs old	Lower resilience was associated with increased waist circumference in the British sample and with increased BMI in the Portuguese sample.
Chedraui et al (2012)	Waist circumference	Resilience Scale (RS-14)	904 Ecuadorian women; pre-menopause, during & post-menopause, 40-59 yrs old	Lower resilience was related to increased abdominal circumference, a greater number of severe hot flushes (self-reported) and increased sedentary lifestyle (self-reported).

Key: yrs = years **Note:** for the Resilience Scale, different versions where reported are denoted by the number of items e.g. RS-25 is the 25 item version

In other areas of health, results were also inconsistent. Robottom et al (2012) reported a lack of association between resilience and Parkinson's Disease severity but there were associations with self-reported factors. Likewise, Wells et al (2011) found an inconsistent relationship between resilience and physical mobility in nuns, showing significant associations with some measures, but not others.

A couple of studies on obesity suggested that lower resilience was associated with increased waist circumference and BMI in healthy participants (Chedraui, et al., 2012; Stewart-Knox, et al., 2012). Lower resilience was also related to a more sedentary lifestyle in Chedraui et al (2012). Links between resilience and health behaviours such as physical activity could provide potential indirect routes between resilience and health. However, indirect relationships were not reported in this study probably because resilience was not the main focus.

Indeed the lack of focus on resilience is an issue for most of the studies reviewed here as it prevents more thorough analysis and investigation (resilience was often just one of a wide range of health related factors). A few studies presented in Table 2.1 were also limited in scope because they had small numbers of participants (e.g. Dolbier, et al., 2001; Hallas, et al., 2003; Steinhardt, et al., 2009) and most were cross-sectional, so did not allow the progression or development of disease or health related factors to be assessed. The limitations of the studies in this area mirror that of the positive wellbeing and health literature (as presented in Chapter 1), whereby the focus, methodology and results of the studies were very heterogeneous, making cross-comparisons difficult.

This is an important area for further investigation because of the growing evidence to suggest that resilience may have health protective effects. The Daytracker study measured a variety of demographic, health behaviour, biological and psychological factors which will allow a thorough exploration of some of the possible indirect links between resilience and health. I would argue that the relatively homogeneous sample of participants in the Daytracker study and the measurement of resilience using a recognised scale will help increase confidence in the significance of the results by reducing variability due to population or measurement differences.

2.6 Understanding the links between resilience and health

Much of our current understanding of the protective effects of resilience on the negative impacts of stress is theoretical rather than based on empirical findings. As discussed above, more resilient people report less stress and have better mental and possibly physical health. Similar to the model of positive affect and health as set out in Chapter 1 (section 1.1), resilience may also influence health via indirect routes such as the stress-related biological correlates of cortisol and heart rate. As I detailed in Chapter 1, positive states and traits are often related to lower levels of cortisol and greater HRV. In turn, these biological factors are associated with beneficial health outcomes such as reduced risk of CVD. A similar illustrative model is proposed to help understand the links between resilience and health. However the emphasis here is on the role of resilience in attenuating the effects of stress (see Figure 2.2).

In McEwen's model of stress and allostasis, individual differences in factors such as genetics and personality are thought to attenuate the link between perceived stress and physiological responses (Karatsoreos & McEwen, 2011; McEwen, 1998; McEwen & Stellar, 1993). In the adapted model seen in Figure 2.2 individual differences in resilience are theorised to influence the stress and physiology relationship. In the original model (McEwen, 1998), there was a single headed arrow from individual differences to perceived stress. This is proposed to be bi-directional in my adapted model because stressful experiences help build resilience and resilience is associated with less stress (as explained in this chapter).

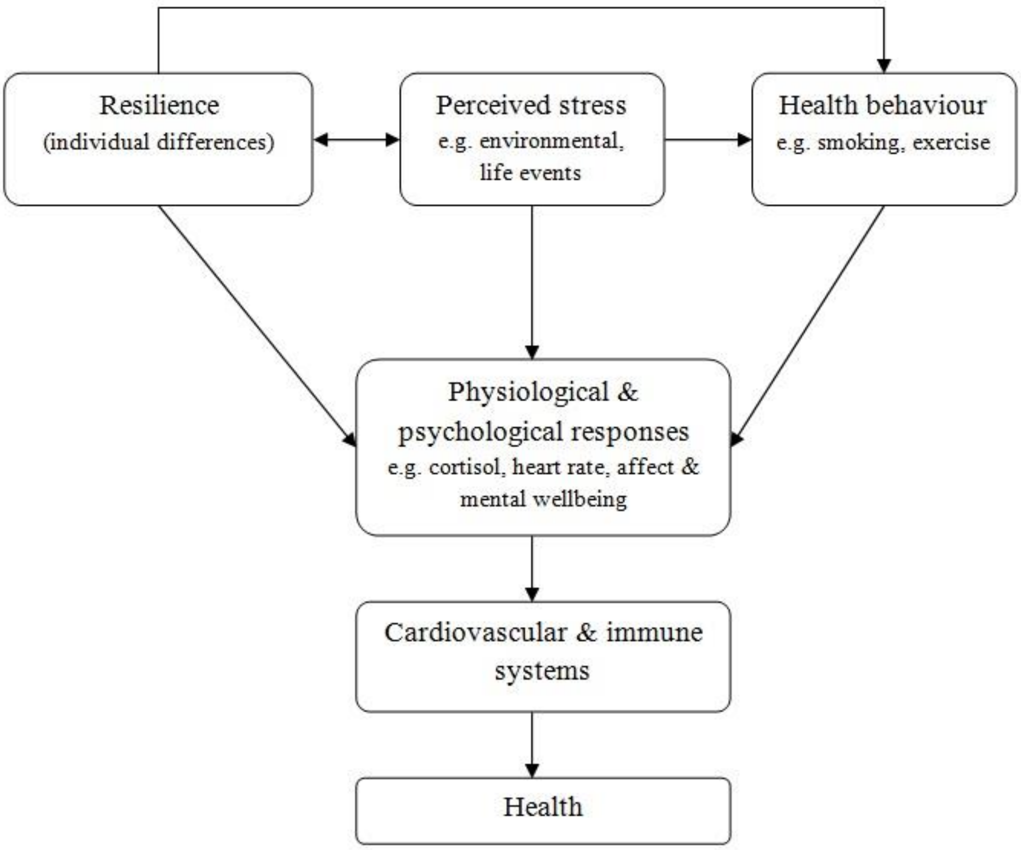


Figure 2.2: A theoretical model illustrating possible links between resilience and health (adapted from Karatsoreos & McEwen, 2011; McEwen, 1998; Pressman & Cohen, 2005)

A link between resilience and behaviour has been added because there is some evidence that higher resilience is associated with beneficial health behaviours such as more frequent exercise (e.g. Pérez-López et al., 2014). Psychological responses are suggested in addition to physiological responses because resilience, stress and health behaviours may influence affect and mental wellbeing. We know that increased stress can result in potentially maladaptive physical and behavioural responses and that these responses can influence physiological and psychological function, which in turn may impact on health (as explained in the previous chapter, see sections 1.4 and 1.5).

The associations between resilience and biological correlates of stress (e.g. cortisol and HRV) are currently under-explored. (I have reviewed the small number of studies investigating resilience and cortisol and HRV in Chapters 5 and 6 respectively). This is surprising considering the relevance of resilience to stress and the range of physical and psychological impacts of stress on health. The studies in the next few chapters therefore present a range of analyses designed to explore these links. The analyses were not designed to specifically test all the links in the model in Figure 2.2 (which is meant to be illustrative) but to explore just some of the relationships relevant to resilience as outlined below.

The first study (Chapter 4) looks at the relationship between resilience, stress and a range of affect and wellbeing outcomes. The aim of this study was to investigate how resilience might attenuate the relationship between stress and mental wellbeing. Chapters 5 and 6 explore the relationship between resilience and cortisol and HRV. These biological measures are relevant to both stress and health, so I thought it would be interesting to see if they are also associated with resilience. Exploring these links will help to identify whether resilience could be health protective via biological mechanisms. Chapter 6 also investigated physical activity, so the relationship between resilience and an example of health-relevant behaviour could be explored. The assessment methods are described in the next chapter.

3 The Daytracker study method

The Daytracker study was an exploratory, international investigation of well-being and biology in everyday life. The study was designed to examine a range of factors in healthy working women including: a) questionnaire assessments of demographic, psychosocial, health behaviours and psychological characteristics, b) daily measures of affect and stress, and c) daily objective measures of cortisol, heart rate and activity. Each of the daily psychological and biological measures was assessed across a work day and a leisure day, to allow comparisons across the days. The study was conducted in 2 cities; London, UK and Budapest, Hungary. I used the Daytracker study data to investigate issues relating resilience with stress and biology. Chapters 4 and 5 present data from the London dataset, as the UK data was available earlier than the Hungarian data. The Hungarian dataset was used to examine HRV in Chapter 6 because the quality of the heart rate data was better than in the UK dataset. The general method is set out below, with a summary of measures used for each study included in the next 3 chapters as appropriate.

3.1 Participants

401 healthy working women were recruited to the Daytracker study (199 to the UK cohort and 202 to the Hungarian cohort). Only women were included in the Daytracker study because women have typically been under-represented in several areas of investigation in the study, such as work stress and heart rate. Despite this under-representation, women are twice as likely than men to suffer from depression (Nolen-Hoeksema, 1990). This factor has been partly attributed to the theory that women may be more susceptible to stress-induced depression due to differences in stress reactivity via the HPA axis (Uhart, Chong, Oswald, Lin, & Wand, 2006; Weiss, Longhurst, & Mazure, 1999).

Inclusion criteria were that the participants should: i) be between 18 to 65 years old, ii) work at least 30 hours per week, and iii) have either English as a first language (in the UK) or Hungarian as a first language (in Hungary). The women were of working age and worked full time, so that measurements could be made during a working day and to allow number of working hours to be broadly comparable. Older women were not included because the biological variables of interest are thought to change with age, particularly over the age of 65 (e.g. Umetani, Singer, Donald, McCraty, & Atkinson, 1998; Van Cauter, Leproult, & Kupfer, 1996). Having either English or Hungarian as a first language (in the UK and Hungary respectively) was preferable since the study included complex sets of instructions and questionnaires written in the native language of each country.

The exclusion criteria included pregnancy, serious illness (either currently or in the last 2 years), and medication including psychotropics and non-steroidal anti-inflammatories. These exclusion criteria were given because medications may influence cardiac activity (e.g. see Gorman & Sloan, 2000; Licht et al., 2008) and alter cortisol regulation (e.g. see Aloisi et al., 2011; Pariante, Thomas, Lovestone, Makoff, & Kerwin, 2004). Likewise, pregnancy may also affect these biological processes (Demey-Ponsart, Foidart, Sulon, & Sodoyez, 1982; Ekholm, Hartiala, & Huikuri, 1997; Voss et al., 2000). Additionally, since the study examined healthy women, participants suffering from serious illness (including mental illness) were excluded from the study. A series of questions were used to screen potential participants for these inclusion and exclusion criteria by e-mail or over the phone.

The participants were recruited via e-mail and leaflets around University College London and Birkbeck, University of London and the Semmelweis University campus in Budapest. Recruitment was stratified by employment grade to enable representation from different socio-economic groups. Ethical approval was obtained from both University College London and Semmelweis University for the study.

3.2 Design

This was a cross-sectional study involving daily measures of affect and biological factors across a work and a leisure day. The starting day for the daily measures was counterbalanced across the participants (half started on a work day, and the other half on a leisure day), see Figure 3.1.

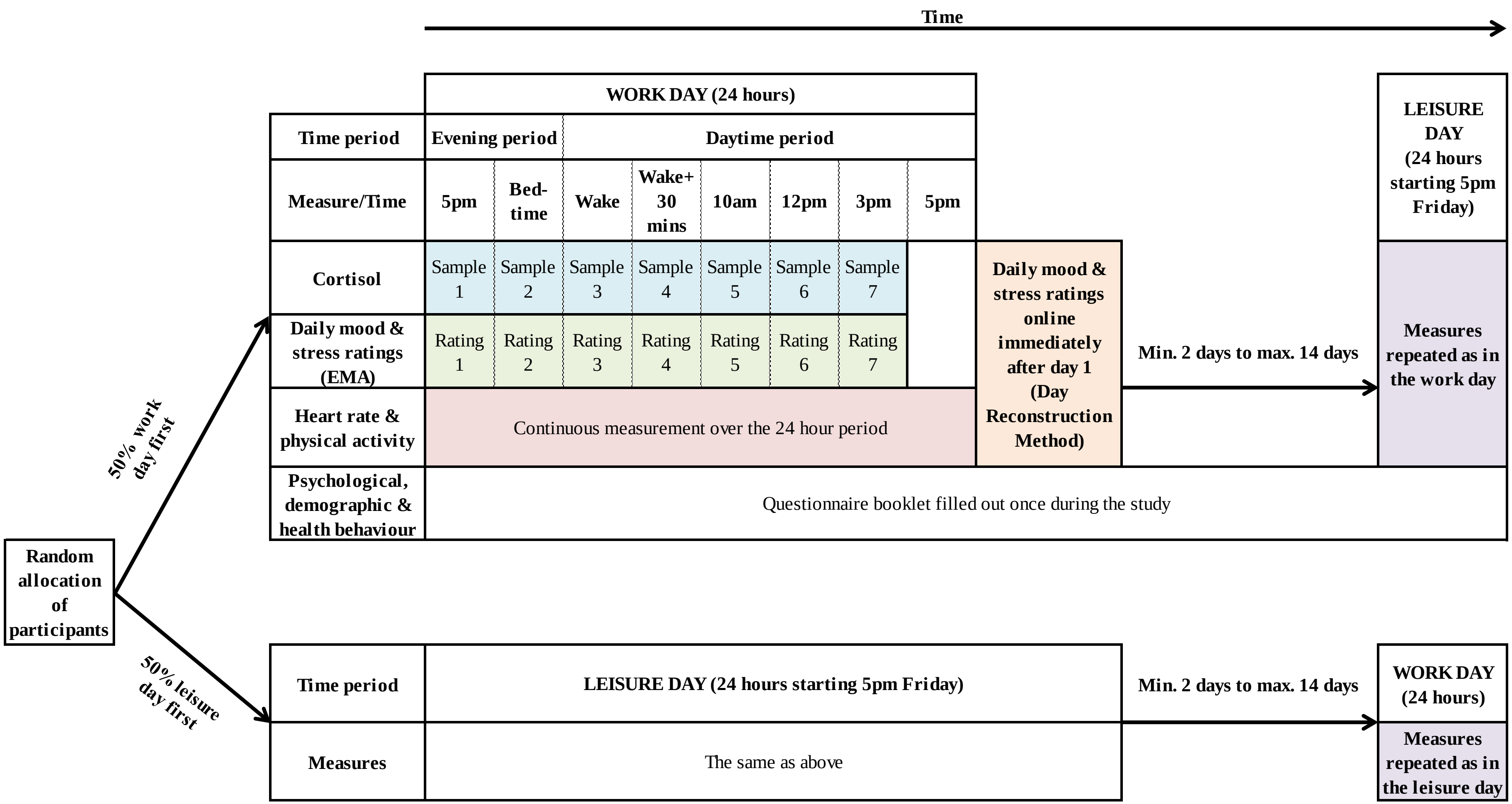


Figure 3.1: Daytracker study design and measures. (EMA = Ecological Momentary Assessment)

3.3 Measures

Biological (cortisol and heart rate) and momentary stress and mood measures were taken across the work day and leisure day periods as seen in Figure 3.1. Psychological, demographic and measures of health behaviour were collected once during the study via questionnaire.

3.3.1 Biological measures

3.3.1.1 Cortisol

Salivary cortisol is strongly correlated with serum cortisol levels and has been identified as a valid method for measuring cortisol in a simple and convenient way (Hellhammer, Wüst, & Kudielka, 2009). Saliva samples were collected by the participants at 7 set times throughout the work and leisure day using salivettes (Sarstedt, Germany). As each monitoring day started at 5pm, the first sample was collected either during, or just after, the participant's visit to the research office (see Figure 3.1). The collection times were: 1) 5pm, 2) bedtime, 3) waking, 4) 30 minutes after waking ('waking+30'), 5) 10am, 6) 12pm and 7) 3pm. The salivettes were numbered from 1 to 7 to reflect each sample time in chronological order.

The participants were asked to fill out a saliva sample diary when taking each sample (see appendix 1 for a copy), indicating the exact time they took the sample, whether there had been a delay between waking and taking the first sample, and whether or not they had brushed their teeth, eaten a meal, drank a caffeinated or alcoholic beverage, smoked, exercised or taken any medication within the 30 minutes prior to taking the sample. Instructions for taking a saliva sample were given orally and in the saliva sample diary as follows:

1) Do not eat or drink anything for 30 minutes before you collect the sample, 2) Remove the small plastic cap, and place the cotton swab in your mouth, avoiding touching it with your hands, 3) Gently chew on the swab until it is soaked, this will usually take about 2 minutes. While you are doing this, answer the questions for this sample in this booklet, 4) Once the swab is soaked, place it back in the tube, trying not to use your hands. Put the cap on securely, and place the tube in the plastic bag provided, 5) Store the bagged tube in a cold place or in a refrigerator.

3.3.1.2 Heart rate and objective physical activity

Combined heart rate monitors and uniaxial accelerometers (Actiheart monitors by CamNtech, Cambridge, UK) were used to provide a continuous recording of heart rate (in beats per minute) and objective physical activity (measured in counts of vertical movement per minute), for two 24 hour periods during a work and leisure day and evening. The Actiheart monitor has been found to be a reliable and valid instrument for measuring activity and single channel recordings of heart rate (Brage, Brage, Franks, Ekelund, & Wareham, 2005).

The Actiheart monitor weighs 10g, is unobtrusive and has two clips attached to standard electrocardiogram (ECG) electrodes. The devise is worn with one electrode placed at V1 or V2 (the 4th intercostal space of the rib cage), and the other electrode about 10cm to the left of the first electrode at V4 or V5, around the mid clavicular line to anterior axillary line (see Figure 3.2). The sampling rate of the accelerometer is 32Hz and the sampling frequency of ECG recordings is 128Hz.

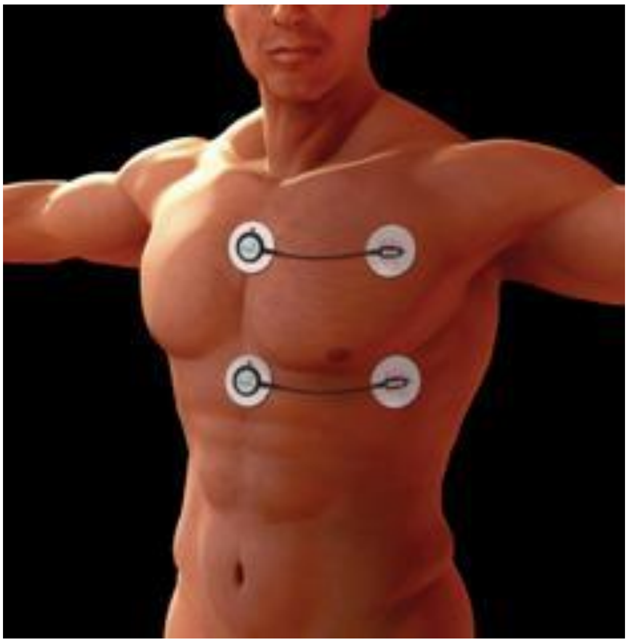


Figure 3.2: Potential locations for wearing the Actiheart monitor (CamNtech, 2010, with permission) Note: one monitor is worn

3.3.2 Daily measures of mood and stress

Psychological variables such as affect and wellbeing are typically assessed with measures of recollected affect. For example, in the Positive and Negative Affect Schedule or PANAS (Watson, et al., 1988) individuals are asked to rate frequency of feelings/emotions associated with positive and negative affect over a few weeks (a global evaluation). Recollected measures typically rely on participants being able to make judgements by averaging experience over specific time frames. These self-assessments may not necessarily reflect daily experience because questionnaire measures are subject to momentary biases according to current mood, recent salient experiences, and other influences on the 'memory-experience gap' (Kahneman & Krueger, 2006; Miron-Shatz, Stone, & Kahneman, 2009). Momentary or daily measures (as used in the Daytracker study described below) may therefore help to remedy this problem.

Day Reconstruction Method measures of affect and stress. An online version of the Day Reconstruction Method (DRM, Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004), was used to determine changes in mood and stress throughout the working and leisure day. The DRM has been established as a reliable measure of experienced affect (Krueger & Schkade, 2008) that relates closely to ecological momentary assessments (Dockray et al., 2010). It is proving valuable in understanding affect and its correlates in everyday life (Michael Daly, Delaney, Doran, Harmon, & MacLachlan, 2010a; White & Dolan, 2009).

The DRM involved the participants filling out a record of events (‘reconstructing’ the previous day) as a series of episodes as in a film. Participants indicated the start and end times of each episode, and provided details such as what they were doing, where they were and with whom. They also completed assessments of how they felt on various affect and stress related parameters using a scale from 0 = *not at all* to 6 = *very much*. These parameters included: 1) happiness, enjoyment, feeling warm and friendly (for positive affect), 2) tiredness, anger, feeling depressed, and worried (for negative affect) and 3) feeling hassled, feeling criticised and frustration (for stress).

Ecological Momentary Assessment (EMA) measures of stress. Ecological Momentary Assessment (EMA, Shiffman, Stone, & Hufford, 2008), was also used to determine participant assessments of daily stress. This method involved the participants completing a rating scale indicating stress levels over the 30 minute period before each saliva sample collection (excluding the waking sample), according to a 5-point scale from 1 = *not at all* to 5 = *very much.* This ratings scale was included as part of the saliva sample diary which the participants were instructed to fill out for each sample (see appendix 1). Thus, there were 6 EMA measures of stress for each monitoring day: at 5pm during the lab meeting, at bedtime, 30 minutes after waking, 10am, 12pm and 3pm the next day.

Composite stress measures were then taken as averages over the work and leisure day periods separately. EMA measures of mood (e.g. happy, sad) were also collected as part of the Daytracker study, but the results were not included in this thesis.

3.3.3 Demographic and health behaviour measures

A wide range of demographic, health behaviour and psychological measures were used in the Daytracker study. Only measures pertinent to the analyses in this dissertation are detailed in this section and listed in Table 3.3.

Demographic measures. Questionnaires were used to collect detailed demographic information (see appendix 2, section A) which was then divided into binary categories as follows: education (less than degree level and degree level or higher), ethnicity (white and other ethnicity), marital status (single/divorced and married) and children (those with and without children). Personal income was grouped into three categories: <£25 000, £25-35 000 and >£35 000 (in the UK) and <HUK 90 000, HUK 90-130 000 and >HUK 130 000 per month in Hungary (approximately <£250, £250-365 and >£365 per month equivalent). Additionally, participant's average self-reported working hours onsite (at the workplace) and at work and home combined were collected.

Health behaviour measures. Participants provided detailed information on smoking behaviour, which was then divided into 2 categories; smokers or non-smokers. Self-reported physical activity was measured using an adaptation of a physical activity scale used in the Whitehall II study (Marmot et al., 1991; Stringhini et al., 2010). See Table 3.3 and appendix 2, section G, for further details.

Table 3.3: Details of health behaviour and psychological questionnaire measures

Type	**Measure**	**Questionnaire**	**Details/ Psychometric properties***
Health behaviour	Smoking	Self-devised questionnaire (see appendix 2, section G)	Questions assessed smoking status & number of cigarettes smoked as applicable
	Frequency of physical activity	Frequency of physical activity (Marmot, et al., 1991). See appendix 2, section G	Participants indicate frequency of moderate activity (e.g. cycling, dancing, scrubbing) & vigorous activity (e.g. running, hard swimming, tennis) using the following categories: 0 = *never, 1 =1-2 times per month, 2=1-2 times per week, 3 = 3 or more times per week*. A total score is calculated by adding moderate & vigorous scores with possible range: 0 (no activity) - 6 (both moderate & vigorous exercise 3+ times per week)
Affect/ wellbeing measures	Resilience	The Resilience Scale (Wagnild & Young, 1993).	14 item questionnaire. Positively worded statements e.g. 'I usually manage one way or another' are rated from 1 = *disagree* to 7 = *agree*. Scores are totalled, range: 14 - 98. Cronbach's α = 0.86 (UK sample) & 0.87 (Hungarian sample)
	Positive and negative affect	Positive and negative affective schedule (PANAS, Watson, et al., 1988)	20 item scale with 10 positive affect related adjectives (e.g. excited, inspired, alert) & 10 negative affect related words (e.g. upset, irritable, afraid). Frequency of experience over the past week is rated from *1 = very slightly/not at all* to *5 = extremely*. Scores are totalled for each subscale, possible range: 10 – 50. Cronbach's α = 0.86 (positive affect) & 0.88 (negative affect). **Note:** PANAS was not measured in the Hungarian dataset
	Depression	Center for Epidemiologic Studies Depression scale (CES-D, Radloff, 1977)	20 item questionnaire assessing symptoms of depression both psychological e.g. 'I felt depressed' & somatic e.g. 'My sleep was restless'. Participants rated how often they had experienced symptoms over the past week from: *0 = rarely/none of the time* to *3 = most or all of the time*. Items 4,8,12 & 16 are reverse scored before calculating total score, range: 0-20. Cronbach's α = 0.88

Affect/ wellbeing measures continued	Sleep problems	Jenkins Sleep Problems scale (Jenkins, Stanton, Niemcryk, & Rose, 1988)	4 item questionnaire assessing frequency of sleep problems e.g. 'How often in the past month did you have you problems falling asleep'. Responses range from *0 = not at all* to *5 = 22-31 days*. The mean score is taken across the 4 items, range: 0-5. Cronbach's α = 0.71
Psycho-social stress measures	Work stress	Effort-Reward Imbalance (ERI) questionnaire (Siegrist, 1996)	2 part questionnaire with 4 subscales (effort, reward, ERI & overcommitment). A 10 item ERI scale assesses effort at work & perceived reward. Items 1-8 are negatively worded e.g. 'I am treated unfairly at work' & rated from *1= no* to *5= yes, very distressed*. Items 9 & 10 are positively worded e.g. 'I receive the respect I deserve from my superiors and colleagues' & rated from *1= yes* to *5 = No, very distressed*. Items on the reward subscale (3, 8, 9, and 10) are reverse scored. Higher scores indicate greater effort or reward with score range (& Cronbach's α): Effort, 6-30 (α = 0.82); Reward, 4-20 (α = 0.66). The ERI subscale is calculated as effort/reward; a score of 1 represents balanced effort & reward, a score >1 indicates greater effort compared to reward. The 5 item overcommitment subscale includes statements such as 'When I get home, I can easily relax and 'switch off' work' to which participants indicate their agreement from *1= strongly disagree* to *4 = strongly agree*. Possible score range (& Cronbach's α): 5-25 (α =0.88)
	Financial stress	Financial strain (Pearlin, Menaghan, Morton, & Mullan, 1981)	7 item questionnaire. Participants indicate how much difficulty they face with various economic issues e.g. 'Do you have problems paying your bills?' from *0 = no difficulty* to *2 = very great difficulty*. Scores are totalled, range: 0-14. Cronbach's α = 0.80
	Local environmental stress	Neighbourhood Problems Scale (Steptoe & Feldman, 2001)	10 item questionnaire. Participants indicate the extent to which issues such as 'litter in the street' are a problem from: *0= not a problem, 1 = some problem, to 2 = serious problem*. Scores are totalled, range: 0 – 20. Cronbach's α = 0.74

*Cronbach's α is given for measures in the UK Daytracker sample (unless indicated otherwise)

3.3.4 Psychological measures

A range of psychological measures were used in the Daytracker study to assess positive factors (e.g. resilience), mental health (e.g. depression), self-reported physical health (e.g. sleep problems) and a number of psychosocial stressors. These measures are listed in Table 3.3 with corresponding Cronbach's alpha calculations for the Daytracker participant data. The alpha values for the questionnaires used in the study ranged from 0.71 to 0.88. This level of internal consistency is thought to be acceptable according to quality assessment guidelines as set out by Terwee and colleagues (2007), therefore we were confident in using these measures in statistical analysis.

Resilience. The Wagnild and Young Resilience Scale has been widely used since 1993, in studies involving different ages and ethnic groups, healthy and patient samples. At the time of project conception for the Daytracker study, the Resilience Scale was considered to be most suitable because of its extensive use and reliability, and because it had been recommended as one of the best resilience scales available at the time (Ahern, Kiehl, Lou Sole, & Byers, 2006). The 14 item scale was selected because it is shorter and has similar reliability to the 25 item version. The Resilience Scale has high internal consistency, with Cronbach's α coefficients ranging from 0.72 to 0.94 (Wagnild, 2009). Inverse relationships between Resilience Scale scores and self-rated mental and physical health problems, along with significant positive associations between resilience and psychological wellbeing, purpose in life and sense of coherence, strengthen the construct validity of the scale (Wagnild, 2009).

Other affect and wellbeing measures. The Positive and Negative Affective Schedule (PANAS, Watson, et al., 1988) and the Center for Epidemiologic Studies Depression scale (CES-D, Radloff, 1977) are both very well used and extensively tested questionnaires with high validity and reliability (Crawford & Henry, 2004; Naughton & Wiklund, 1993). The Jenkins Sleep Problems scale (Jenkins, et al., 1988) was chosen as a measure of sleep difficulties as it is short (4 items) and was therefore suitable for the large questionnaire pack used in the Daytracker study. The Jenkins Sleep Problems scale is commonly used in clinical and epidemiologic studies and has good internal reliability (Jenkins, et al., 1988; Lallukka, Dregan, & Armstrong, 2010)

Psychosocial stress measures. Three questionnaire measures of stress were included in the Daytracker study. The Effort-Reward Imbalance (ERI) questionnaire (1996) is a commonly used measure of work stress which has been used to assess health and wellbeing according to individual differences in effort, reward and overcommitment at work (e.g. Siegrist, 2010; Steptoe, Siegrist, Kirschbaum, & Marmot, 2004). It is a particularly useful measure since it has 3 subscales (effort, reward and overcommitment), together with a combined measure of effort-reward imbalance which looks at job demands relative to perceived reward. The questionnaire has been well validated with good reliability (Siegrist et al., 2004).

There are relatively few questionnaires specifically designed to assess economic stress and local environmental stress, since many studies in this field either devise their own questions or use other data such as actual income or government reports on neighbourhood deprivation. However, the Daytracker study was interested in perceived stress rather than actual environmental or economic factors. Financial strain (Pearlin, et al., 1981) was used to assess economic stress and the Neighbourhood Problems Scale (Steptoe & Feldman, 2001) for local environmental stress, as both have good reliability and have been used in a number of health relevant studies (e.g. Friedman, Conwell, & Delavan, 2007; Pearlin, et al., 1981; Schütte, Chastang, Parent-Thirion, Vermeylen, & Niedhammer, 2014; Sooman & Macintyre, 1995; Steptoe & Feldman, 2001; Wang, Schmitz, & Dewa, 2010). Both scales are also relatively short and simple to fill out as they each have only 3 response choices.

3.4 Procedure

Participants attended the research office individually at the end of a work day, where the procedure was explained and they were asked to give signed consent to take part in the study. During the lab visit the participants were issued with a questionnaire pack, a set of salivettes for collecting saliva samples and were given instructions for completing the saliva sample diary, daily affect and stress measures. Additionally, each participant was fitted with an Actiheart monitor. Height and weight were measured by the researchers (to calculate BMI), and the start date of the participant's last menstrual period was recorded to estimate menstrual phase.

Half the participants started the study from Monday to Thursday (work day first), and half started on Friday after work (leisure day first). Each monitoring day lasted 24 hours, beginning at 5pm (as the participants attended the lab either just before, or after the end of the working day) and ending at 5pm the following day (see Figure 3.1). During each monitoring day, the participants collected saliva samples at 7 time points, completed a saliva sample diary (which also included momentary measures of stress and mood) and wore the Actiheart monitor continuously. DRM measures were completed online either at work or at home depending on the location of the participants at the end of each monitoring day. The participants recorded the daily events across the previous 24 hours starting at 5pm the previous day (at the start of the monitoring day).

The participants were asked to return the Actiheart monitor, saliva samples and diary as soon as possible after collection (usually the next day, or Monday, if the collection period was a leisure day). Salivary cortisol samples can be kept at room temperature for several days without degradation (Clements & Parker, 1998), but the participants were asked to refrigerate and then return the samples as quickly as possible as a precautionary measure. Returned saliva samples were immediately transferred to a freezer, before being couriered to an external laboratory (at the Technical University Dresden, Germany), where the samples were assayed for salivary cortisol using high-sensitivity enzyme immunoassay.

After completing the first monitoring day, the participants returned to the lab where the procedure was repeated for the second monitoring day. All participants completed two days of monitoring, and the work and leisure assessment periods were separated by a minimum of 2 days and a maximum of 14 days. The questionnaire pack was completed at home and returned at the end of the study. The participants were given a small honorarium for their time.

3.5 Data collection

The data was collected by Dr. Samantha Dockray, Dr. Romano Endrighi and Dr. Nina Grant in the UK, and by Dr. Gyöngyvér Salavecz in Hungary. Data collection took place simultaneously in the UK and Hungary, between April 2007 and September 2008. The project was devised and supervised by Dr. Samantha Dockray, Prof. Andrew Steptoe and Prof. Maria Kopp. The study was funded through grants from the National Institute on Aging (NIH) and the Economic and Social Research Council (ESRC). Prof. Andrew Steptoe was the Principal Investigator on these grants, and the co-investigators were Prof. Jane Wardle and Sir Michael Marmot (UCL), Prof. Daniel Kahneman (Princeton University) and Prof. Arthur Stone (Stony Brook University).

3.6 Daytracker study analyses

To explore associations between resilience, stress and health related biological factors, I carried out secondary analyses on data collected as part of the Daytracker study. The following 3 chapters present a selection of results from these analyses. Chapter 4 examines the relationship between resilience, chronic stress and various affective and wellbeing outcomes. The second study (Chapter 5), presents associations between resilience, depressive symptoms and cortisol. The final study (Chapter 6) looks at the associations between resilience, physical activity (as a health behaviour) and heart rate variability (HRV), as a biological marker of health. Specific details of data and statistical analysis are described in each study chapter, although the main analyses were all multiple linear regression because the data was cross-sectional.

4 Resilience as a mediator of the effects of psychosocial stress on affect and wellbeing

4.1 Introduction

Despite a number of studies suggesting that greater resilience is associated with a) less perceived stress and b) better mental health and positive wellbeing, there is a lack of direct evidence to demonstrate that resilience attenuates the effects of stress on wellbeing (as discussed in Chapter 2). In particular, the protective role of resilience under conditions of chronic (ongoing) stress and the effects of multiple stressors remains underexplored. The potential mediating or moderating role of resilience on the association between different types of chronic stress and affect and wellbeing was therefore tested in this analysis. The stress exposures were work stress, construed using Siegrist's (1996) effort-reward model, stress from the local environment (neighbourhood problems), and financial strain; all may increase the risk of mental and physical health problems. These measures are especially pertinent to the current economic recession where there may be more demands in the workplace with less financial reward.

4.1.1 Stress exposures

Siegrist's (1996) model of effort-reward imbalance (ERI) asserts that people are more likely to suffer from prolonged stress and negative affect in work situations where there is high effort (e.g. substantial job demands) and low reward (e.g. little prestige or low salary) together with high over-commitment. Several studies have found associations between high ERI and negative health outcomes such as increased levels of depression, anxiety and burnout (e.g. Godin, Kittel, Coppieters, & Siegrist, 2005; Kivimäki, Vahtera, Elovainio, Virtanen, & Siegrist, 2007; Pikhart et al., 2004; Reineholm, Gustavsson, &

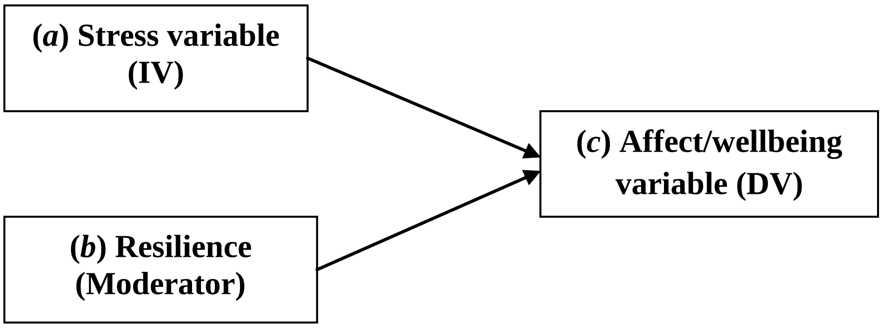
Ekberg, 2011), poorer self-reported health (Kivimäki, et al., 2007; Krause, Rugulies, & Maslach, 2010; Niedhammer, Tek, Starke, & Siegrist, 2004) and increased risk for cardiovascular disease (e.g. Kivimäki et al., 2002; Kuper, Singh-Manoux, Siegrist, & Marmot, 2002; Xu, Zhao, Guo, Guo, & Gao, 2009). Additionally, over-commitment has been related to poorer self-reported health (Niedhammer, et al., 2004), burnout (Bagaajav, Myagmarjav, Nanjid, Otgon, & Chae, 2011; Yeh, Cheng, Chen, Hu, & Kristensen, 2007) and increased fatigue, especially when in combination with high ERI (Takaki, Nakao, Karita, Nishikitani, & Yano, 2006). Studies of biological correlates and work stress (using Siegrist's model) have found associations between overcommitment and under-activity of the HPA axis following pharmacological stimulation in the lab (Wolfram, Bellingrath, Feuerhahn, & Kudielka, 2013), and elevated cortisol output and ambulatory systolic blood pressure in a naturalistic setting (Steptoe, et al., 2004).

Work stress only captures part of the adversity to which people are exposed. A second area relates to the conditions in which people live, operationalised in this study as neighbourhood problems. Greater perceived neighbourhood problems (such as noise and traffic pollution) have been associated with poor self-rated health (Schütte, et al., 2014; Steptoe & Feldman, 2001), impaired physical function (Yen, Yelin, Katz, Eisner, & Blanc, 2008), and higher levels of depression (Carter, Williams, Paterson, & Iusitini, 2009; Echeverria, Diez-Roux, Shea, Borrell, & Jackson, 2008). Similarly, financial strain has been associated with increased risk of major depressive disorder (Friedman, et al., 2007; Wang, et al., 2010), reduced perceived health status (Chiao, Weng, & Botticello, 2012), and higher levels of burnout in women (Soares, Grossi, & Sundin, 2007; Sundin, Soares, Grossi, & Macassa, 2011).

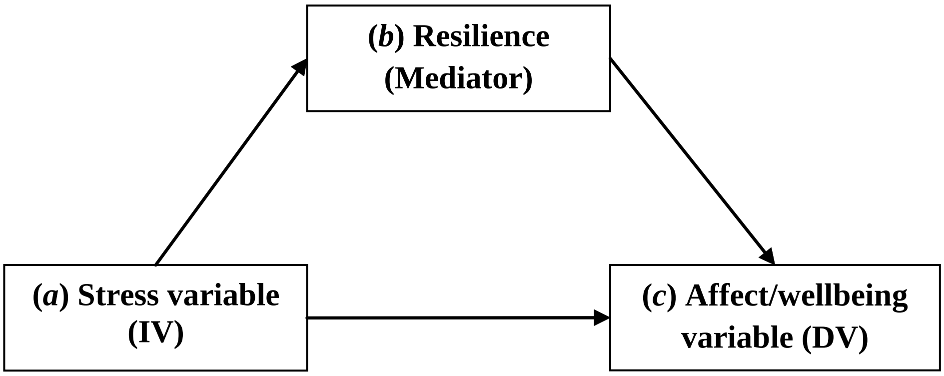
4.1.2 Resilience as a protective factor

There are likely to be negative health impacts associated with of each of these psychosocial stressors. However, the role of resilience in reducing the impact of these *particular* stressors is yet to be determined. To explore this, the interrelationships between stress, resilience and a range of affect and wellbeing outcomes (depression, sleep problems, negative affect and positive affect) were investigated. I expected the results of this study to follow the same pattern as in previous research: higher stress levels should be associated with lower resilience, and lower resilience should be related to increased symptoms of depression, negative affect and sleep problems and reduced positive affect. If resilience has a protective role, then associations between stress exposure and affective outcomes should be mediated or moderated by resilience. Either resilience will reduce the impact of the stress measures on negative outcomes (mediation) or associations between stress and negative outcomes will vary according to the level of resilience (moderation).

Figure 4.1 illustrates the potential mediating or moderating relationships between stress (as an independent variable), resilience (as the moderator/mediator) and the affect/wellbeing outcomes. The conditions for mediation are that the independent variable (IV) must significantly predict both the mediator (resilience) and the dependent variable (DV). The mediator must significantly predict the DV and the effect of the IV on the DV should be reduced with the addition of the mediator to the regression (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). According to Baron and Kenny (1986) moderation occurs when two IVs (*a* and *b*), independently predict the same DV (*c*), but are usually not related to each other. The association between *a* and *c* is conditional upon *b*, when *a* and *b* are combined in a regression model. The relationship differs depending on the level of *b*, which acts as a moderator between *a* and *c*.



Resilience as a moderator (above)



Resilience as a mediator

Figure 4.1: Diagrams illustrating resilience as a moderator (top) or mediator (bottom). Key: IV= independent variable, DV= dependent variable

In the proposed models chronic stress and resilience are relatively enduring factors so they have been placed as independent variable and mediator/moderator respectively. Resilience has been posited as a mediator/moderator variable based on previous research (e.g. Ong, et al., 2009) and to test the theory that resilience reduces the impact of stress on affect/wellbeing. It is less likely that affect/wellbeing measures would be predictive of stress or resilience. However, it should be noted that the variables in the model could potentially be placed in a different order.

If moderation occurs then the nature of the relationship between stress exposure and affect/wellbeing will change as a function of resilience. For example, there may be a positive relationship between stress exposure and depression in people categorised as having low resilience, whereas this relationship may not be present in people with high resilience. If there is no moderation then the nature of the relationship between stress and depression will be the same whether people have high or low resilience. Under conditions of mediation the relationship between stress and depression will operate via a third variable (resilience) i.e. there will be indirect effects. If mediation is present then the relationship between stress and depression will be weakened (or reduced to zero) by including resilience as a mediator.

It is currently difficult to predict whether resilience is more likely to act as a moderator or mediator, since there are very few studies that specifically test moderation or mediation in this context (hence the value of this analysis). Resilience has been theorised to mediate the impact of stress on wellbeing (Feder, et al., 2009). Other theories suggest resilience could act as a moderator or a mediator depending on how it is conceptualised. For example, when resilience is viewed in terms of a coping style it is suggested to moderate the relationship between stress and mental wellbeing. However, when resilience is seen as an outlook on life, it is thought to mediate the association between life stressors and wellbeing (Cohen & Edwards, 1989). Since resilience is conceived as including both coping strategies and more enduring traits like optimism according to the Resilience Scale, either of these options could apply to the current analysis.

The small amount of empirical evidence for the role of resilience as either a moderator or mediator is not conclusive. Ong et al. (2009) found that the relationship between daily stress and negative affect on the following day was moderated by ego resilience, which in turn was mediated by positive affect. They suggested that positive affect helps people with higher trait resilience to recover from daily stress. However, Aroian and Norris (2000) found no evidence to suggest that resilience mediated or moderated the association between immigration stress and depression in female Russian immigrants. Based on the available evidence it seems more likely that resilience will act as a moderator (since the Ong study was the only significant finding). However, this suggestion is necessarily tentative since Ong used a very different method to the current study; they measured ego resilience which has a different conceptual basis to the Resilience Scale (as mentioned in Chapter 2).

An additional measurement related issue concerns the assessment of affective outcomes. As mentioned in Chapter 3, wellbeing is typically assessed with measures of recollected affect. These may not necessarily equate to daily experience because questionnaire measures can be influenced by momentary biases such as current mood. Therefore, measures of both questionnaire and daily affect (using the Day Reconstruction Method) were included in this study. We were therefore able to study whether the mediating or moderating role of resilience would be apparent both in questionnaire and daily measures of affect.

4.2 Method

The data for this study was analysed from 197 healthy working women from the London Daytracker study. The mean age was 33.8 years (±9.28) with a range of 21-61 years. Aside from resilience, this study included measures of psychosocial stress, affect and wellbeing (further detail on these measures can be seen in Chapter 3). The measures of psychosocial stress were work stress (Siegrist, 1996), financial strain (Pearlin, et al., 1981) and local environmental stress assessed using the Neighbourhood Problems Scale (Steptoe & Feldman, 2001). The PANAS (Watson, et al., 1988), the CES-D (Radloff, 1977) and the Jenkins Sleep Problems scale (Jenkins, et al., 1988) were used to measure positive and negative affect, depression and sleep difficulties respectively. In addition, the DRM (Kahneman, et al., 2004), was used to determine daily positive and negative affect during the working and leisure day. The DRM was completed online at the end of each monitoring day. All other measures were assessed once during the study via questionnaire.

4.2.1 Data analysis

DRM measures. The mean of each individual DRM measure (e.g. happy, sad) was calculated across the day and evening periods separately for both the work and the leisure day (making a total of 4 means for each DRM measure per participant as defined in Table 4.2). For example, there was a separate mean score for DRM happiness for the work day, work evening, leisure day and leisure evening. Aggregate variables of ‘DRM positive affect’ and ‘DRM negative affect’ were then constructed for each of the 4 periods as averages of the mean scores of the following measures: Positive affect = happiness, enjoyment and feeling warm/friendly, Negative affect = anger, depression and worry. In other words, DRM positive and negative affect were means of mean scores for the appropriate variables.

Table 4.2: Time periods for DRM mean scores

	Evening		Day	
	Start	**End**	**Start**	**End**
Work	5pm after work	Bedtime	Waking the next day	5pm the next day
Leisure	5pm on a Friday	Bedtime	Waking the next day	5pm the next day

Stress load. An aggregate variable labelled 'Stress load' was calculated to provide an indication of cumulative stress exposure across the different stress domains. Stress load was calculated by summing the z-scores of effort-reward imbalance, over-commitment, neighbourhood problems and financial strain. Higher scores on the stress load measure indicate greater stress exposure.

4.2.2 Statistical analysis

Statistical analysis was carried out using SPSS, version 19. Bivariate correlations, t-tests or analyses of variance were conducted as appropriate to assess whether resilience was associated with demographic measures. The dependent variables in the main analyses were the measures of affect and wellbeing (depressed mood, sleep problems and PANAS and DRM measures of affect). The independent variables were the measures of stress including the subscales of work stress (effort, reward, effort-reward imbalance and overcommitment), neighbourhood problems and financial strain. Resilience was treated both as a dependent variable and an independent variable in the different analyses detailed below. Associations between stress exposures, resilience and affect/wellbeing outcomes were analysed using multiple linear regressions. Each stress measure was regressed on resilience separately. Resilience was then regressed on each of the affect and wellbeing outcomes. All regression models were adjusted for age, income and parental status. Depression has been associated with socioeconomic factors including income (e.g. see Zimmerman & Katon, 2005) and since we assessed sleep problems and affect across the previous 24 hours, we reasoned that having children could be an important factor. Additionally, age has been related to both sleep problems and depressive symptoms (Kessler, Foster, Webster, & House, 1992; Vitiello, Larsen, & Moe, 2004). Results are presented as standardized betas with standard errors. The presence of multicollinearity was checked by calculating Variance Inflation Factors (VIFs) for each analysis. The highest VIF was 1.624, which does not indicate the presence of multicollinearity (Belsley, Kuh, & Welsch, 1980).

Further analyses were conducted to see whether resilience mediated or moderated the associations between stress variables and affect and wellbeing using Hayes' (2013) syntax for mediation and moderation analysis in SPSS (downloaded from http://www.processmacro.org). Sobel's test (1982) was used to assess indirect effects. The presence of the necessary relationships between IV, mediator and DV as outlined in the introduction was required for mediation, as well as the presence of indirect effects. Moderation was detected by regressing the interaction of stressor x resilience (as a binary variable categorised as high and low resilience) on the affect and wellbeing outcomes (Hayes, 2013).

4.3 Results

The demographic characteristics of the research sample are shown in Table 4.3. The mean age was 33.8 years and the participants worked an average 41.3 hours per week in total. The majority of the participants was white European, educated to degree level or higher, did not have children and earned an income of between £25-35,000 (personal income) and £35-70,000 as a household. There were roughly equal numbers of married and single/divorced participants.

Resilience scores ranged from 27 to 84 (mean 60.4 ±10.9) and were fairly normally distributed as seen in Figure 4.4. Resilience was not related to education, ethnicity, marital status, or hours of work. However, participants in the highest income category were more resilient (mean 64.7 ±10.3) than those in the intermediate and lower income groups (means 59.1 ±10.3 and 59.0 ±11.4, respectively, $F(2, 192) = 5.88$, $p = 0.003$), and these differences remained significant when age was included as a covariate. Participants with children were more resilient than those without (means 65.8 ±9.98 and 59.4 ±10.8, $t = -2.96$, $p = 0.003$). In multiple regression on resilience scores, personal income ($\beta = 0.197$, S.E.= 0.076, $p = 0.010$), age ($\beta = -0.228$, S.E.= 0.084, $p = 0.007$), and children ($\beta = 0.267$, S.E.= 0.08, $p = 0.01$) were independent predictors.

Table 4.3: Demographic (a) and psychological characteristics (b) of the study participants

(a) Demographic & hours of work

Characteristic	**N (%)**
Education	
Less than degree	71 (36.0)
Degree or higher	126 (64.0)
Marital status	
Single/divorced	96 (49.5)
Married	98 (50.5)
Has children	
Yes	29 (14.7)
No	168 (85.3)
Ethnicity	
White European	160 (81.2)
Other	37 (18.8)
Personal income	
<£25,000	64 (32.5)
£25,000-£35,000	87 (44.2)
>£35,000	46 (23.3)
	Mean (SD)
Age, yrs	33.8 (9.28)
Hours of work	
Hours of work onsite	37.9 (5.87)
Total hours of work	41.3 (7.40)

(b) Psychological characteristics

Characteristic/measure	**Mean (SD)**
Resilience	60.4 (10.9)
Work stress	
Over-commitment	11.2 (2.38)
Effort/reward imbalance (ERI)*	.725 (.508)
Effort	11.5 (4.31)
Reward	17.4 (2.93)
Psychosocial stress	
Financial strain	4.71 (3.08)
Neighbourhood problems	4.54 (3.20)
Affect & wellbeing questionnaire measures	
Depression	12.1 (8.63)
Positive affect (PANAS)	33.1 (7.12)
Negative affect (PANAS)	19.5 (7.12)
Sleep problems	1.59 (0.96)
DRM measures of affect	
Positive affect	
Work day	3.01 (1.14)
Leisure day	3.59 (1.15)
Work evening	3.32 (1.13)
Leisure evening	3.58 (1.04)
Negative affect	
Work day	0.87 (0.94)
Leisure day	0.59 (0.91)
Work evening	0.72 (0.93)
Leisure evening	0.65 (0.87)

*ERI score <1 = greater reward compared to effort, 1 = effort & reward equal, >1 = greater effort compared to reward

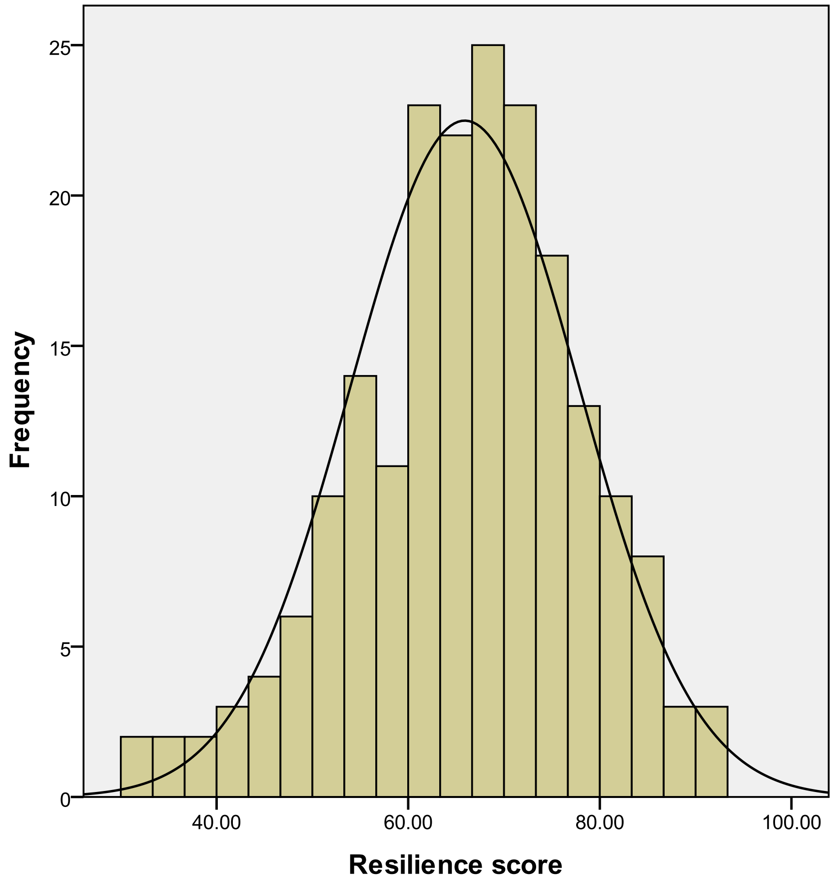


Figure 4.4: Frequency histogram of resilience scores

4.3.1 Psychosocial stress and resilience

Table 4.5 shows regression analyses of each stress measure (predictor) individually regressed on resilience as the DV (means and standard deviations for all measures can be seen in Table 4.3). Resilience was negatively associated with over-commitment at work, neighbourhood problems, and total stress load, while being positively related to perceived rewards at work. These results indicate that more resilient individuals report less exposure to chronic life stress. There was no association between resilience and financial strain, effort and effort-reward imbalance.

Table 4.5: Regression analyses of each psychosocial stress factor as a predictor of resilience (DV), adjusted for age, income and parental status

Psychosocial variable (predictor)	β	SE	p	R^2
Work stress				
Effort	-.078	.075	.300	.094
Reward	.232	.069	.001**	.145
Effort/reward imbalance	-.098	.072	.176	.098
Overcommitment	-.176	.071	.014*	.123
Neighbourhood problems	-.172	.068	.012*	.123
Financial strain	-.126	.074	.091	.102
Stress load	-.231	.069	.001**	.137

*p<0.05, **p<0.01

Key: β=standardised regression co-efficient for each psychosocial stress factor, SE = standard error

4.3.2 Resilience and affect and wellbeing questionnaire measures

Mean (SD) scores on the affect and wellbeing questionnaires (PANAS positive and negative affect, depression and sleep problems), are shown in Table 4.3. There were positive correlations between depression and PANAS negative affect ($r = 0.70$, $p < 0.001$) and between depression and sleep problems ($r = 0.33$, $p < 0.001$). PANAS positive affect was in turn negatively associated with depressed mood ($r = -0.42$, $p < 0.001$) and sleep problems ($r = -0.18$, $p = 0.013$).

In multiple regression, the four questionnaire measures of affect and wellbeing (as DVs) were all significantly associated with resilience (Table 4.6). Positive affect on the PANAS showed a positive association with resilience, whereas depression, negative affect on the PANAS and sleep problems were negatively related to resilience. An additional set of regressions included negative affect from the PANAS as a covariate to control for negative affectivity reporting bias (regression model 2). The associations of resilience with depression, positive affect and sleep problems remained significant.

Table 4.6: Regression analyses of resilience (as a predictor) on each affect and wellbeing questionnaire measure (DV)

	Regression model 1[a] (resilience as predictor)				Regression model 2[b] (resilience as predictor, adjusted for negative affect)			
Affect/well-being measure (DV)	**β**	**SE**	**p**	**R^2**	**β**	**SE**	**p**	**R^2**
CESD depression	-.565	.061	.001	.353	-.387	.050	.001	.630
PANAS positive affect	.571	.063	.001	.318	.644	.066	.001	.355
PANAS negative affect	-.348	.071	.001	.147	-	-	-	-
Jenkins sleep problems scale	-.281	.070	.001	.169	-.229	.075	.001	.185

Key: [a]**Regression model 1** = adjusted for age, income and parental status, [b]**Regression model 2** = as model 1, plus additionally adjusted for negative affect, **β**= standardised regression co-efficient for resilience, **SE** = standard error

4.3.3 Resilience and DRM affect measures

DRM positive affect was significantly higher for the leisure day compared with the work day (t= -6.367, p<0.001), and for the leisure evening compared with the work evening (t= -2.394, p= 0.018, see Table 4.3 for means). Conversely, mean DRM negative affect scores were higher on the work day versus leisure day (t= 3.734, p< 0.001). Although mean negative affect was also higher on the work evening versus leisure evening, this difference was not significant (t= 1.148, p= 0.253). In a series of regression analyses, resilience was associated with DRM positive affect for all time periods, but was only a significant predictor of DRM negative affect on the leisure day and evening, and not on the work day (Table 4.7).

Table 4.7: Regression analyses of resilience (as predictor) on DRM measures of positive and negative affect (DV), adjusted for age, income and parental status

DRM affect (DV)	Time period	Monitoring period	β	SE	p	R^2
Positive Affect	**Day**	**Work**	.168	.080	.037*	.096
		Leisure	.222	.079	.005**	.135
	Evening	**Work**	.176	.077	.023*	.058
		Leisure	.191	.079	.017*	.062
Negative Affect	**Day**	**Work**	-.113	.083	.176	.034
		Leisure	-.171	.082	.039*	.061
	Evening	**Work**	-.092	.078	.241	.026
		Leisure	-.155	.078	.049*	.093

*p<0.05, **p<0.01

Key: β= standardised regression co-efficient for resilience, **SE** = standard error

4.3.4 Resilience as a mediator between stress and affect and wellbeing

As the psychosocial measures of reward and over-commitment, neighbourhood problems and total stress load were associated with resilience, and resilience was in turn related to affect and wellbeing measures, we tested the possibility that resilience could be a mediator of the impact of stress on affect and wellbeing. The results of Sobel tests are shown in Table 4.8. This table shows unstandardised beta values to allow changes in beta to be assessed for each variable with the addition of resilience to the model.

Table 4.8: Regression and Sobel analyses for resilience as a mediator between psychosocial stressors (IV) and (a) depression, (b) negative affect and (c) sleep problems (DV)

(a)

		Depression (DV)							
		Regression					Sobel test		
Stress variable (IV)	Model	b	95% CI Lower	95% CI Upper	p	R^2	Test value	SE	p
Over-commitment	1[a]	.950	.442	1.46	.001***	.128	.331	.149	.026*
	2[b]	.609	.170	1.05	.007**	.378			
Reward	1[a]	-1.31	-1.68	-0.93	.001***	.250	-.378	.111	.001***
	2[b]	-.976	-1.31	-0.64	.001***	.451			
Neighbour-hood problems	1[a]	.650	.287	1.01	.001***	.123	.292	.111	.009**
	2[b]	.440	.124	0.76	.007**	.378			
Stress load	1[a]	1.86	1.41	2.31	.001***	.303	.451	.135	.001***
	2[b]	1.47	1.07	1.86	.001***	.498			

*p<0.05, **p≤0.01, ***p≤0.001

(b)

		Negative affect (DV)							
		Regression					Sobel test		
Stress variable (IV)	Model	b	95% CI Lower	95% CI Upper	p	R^2	Test value	SE	p
Over-commitment	1[a]	.660	.226	1.09	.003**	.082	.181	.083	.029*
	2[b]	.473	.049	.897	.029*	.169			
Reward	1[a]	-.853	-1.18	-.523	.001***	.155	-.186	.066	.005**
	2[b]	-.691	-1.02	-.362	.001***	.219			
Neighbour-hood problems	1[a]	.493	.187	.799	.002**	.087	.149	.062	.016*
	2[b]	.398	.097	.699	.010**	.177			
Stress load	1[a]	1.48	1.10	1.86	.001***	.260	.196	.074	.008**
	2[b]	1.31	.926	1.69	.001***	.312			

*p<0.05, **p≤0.01, ***p≤0.001

(c)

Stress variable (IV)	Model	Sleep problems (DV): Regression b	95% CI Lower	95% CI Upper	p	R^2	Sobel test: Test value	SE	p
Over-commitment	**1[a]**	.105	.049	.161	.001***	.155	.019	.010	.052
	2[b]	.087	.032	.141	.002**	.211			
Reward	**1[a]**	-.057	-.102	-.011	.015*	.102	-	-	-
	2[b]	-.037	-.081	.008	.108	.159			
Neighbour-hood problems	**1[a]**	.028	-.013	.070	.170	.101	-	-	-
	2[b]	.006	-.035	.046	.781	.170			
Stress load	**1[a]**	.119	.064	.175	.001***	.171	.028	.011	.010**
	2[b]	.096	.041	.151	.001***	.219			

*p<0.05, **p≤0.01, ***p≤0.001

Key: DV = dependent variable, **b** = unstandardized regression coefficient for the psychosocial stress factor on affect or wellbeing, with 95% confidence intervals (**CI**), **Test value** = Regression coefficient for the Sobel tests with standard errors (**SE**), **[a]Model 1** = Adjusted for age, income, and parental status, **[b]Model 2** = As model 1 plus adjusted for resilience

Note: Sobel tests were not performed when models were not significant

In regression models with depression as the dependent variable (Table 4.8a), all 4 psychosocial stressors were significantly associated with depression (model 1). When resilience was added to the analyses in model 2, these associations were reduced but remained significant. Results from the Sobel tests indicated that resilience was a mediator of the impact of each of the psychosocial stressors on depression. A similar series of analyses (as shown in Table 4.8b) revealed that resilience was a mediator of the impact of each of the psychosocial stressors on negative affect. As seen in Table 4.8(c) resilience mediated between stress load and sleep problems only. Although overcommitment was associated with sleep problems in models 1 and 2, the Sobel test was not significant. Reward was only associated with sleep problems in model 1 but not model 2, and neighbourhood problems was not associated with sleep problems in regression. Therefore Sobel tests were not conducted for reward and neighbourhood problems as predictors of sleep problems. Resilience was a partial mediator in all cases, because although the relationships between the stressors and dependent variables were significantly decreased when adjusting for resilience, they were not reduced to zero.

Resilience did not mediate between any of the psychosocial stress measures and positive affect from the PANAS (DV). This was because none of the stress measures that were related to resilience (reward, overcommitment, neighbourhood problems and stress load) significantly predicted positive affect in regression (results not shown). Resilience was not a significant mediator between any of the stress measures and the daily affect measures for any time periods (results not shown). This was because neighbourhood problems and over-commitment were not significant predictors of the DRM affect measures. Reward was a significant predictor of DRM positive affect and negative affect for the leisure evening and negative affect for the leisure day; however, the addition of resilience to each regression rendered reward a non-significant predictor.

4.3.5 Adjusting for multiple comparisons

So far the analyses in Table 4.8 have not been adjusted for multiple comparisons. A Bonferroni correction of the significance level suggests that the analyses should be considered as significant where $p \leq 0.017$. Adopting a more stringent significance level means that resilience no longer mediates between i) overcommitment and depression, and ii) overcommitment and negative affect.

4.3.6 Resilience as a moderator between stress and affect/wellbeing

Resilience (as a binary variable) did not moderate the relationships between any of the stressors and the daily affect and questionnaire affect/wellbeing outcomes ($p= .275$ to $p= .892$).

4.4 Discussion

This study examined the relationship between resilience, psychosocial stress, and wellbeing, and also explored the potential role of resilience as a mediator or moderator. The results indicate that greater exposure to life stress was associated with lower resilience independently of demographic covariates, and that high resilience was in turn related to lower levels of negative affect, depressed mood and sleep problems. Resilience was also associated with higher positive affect assessed both with questionnaires and measures of experienced affect derived from the DRM. Evidence of resilience mediating between stress exposure and affective outcomes emerged from analyses of questionnaire measures, but not of DRM-derived outcomes. The reason for this was partly because mediation tests failed, and partly because a precondition for mediation – that stress exposure would be associated with DRM measures – was not consistently fulfilled. Resilience did not moderate any of the relationships.

The direction of the relationship between measures of stress exposure and resilience cannot be determined in this cross-sectional study. It may be, for example, that those with higher resilience experience fewer neighbourhood problems because they live in better areas, or report fewer problems because they cope more effectively with day to day hassles. It should be noted that this relationship remained significant after personal income had been taken into account. Income may be a determinant of the quality of domestic neighbourhood, so the second of these two explanations seems more plausible. The lack of association between financial strain and resilience was interesting considering that there was a relationship with personal income. Perhaps financial strain was not relevant here because the sample was moderately affluent, with only a third of the participants earning less than £25 000 per year.

It is interesting that over-commitment rather than other measures of work stress was associated with resilience. According to the Siegrist model, over-commitment reflects an immersion in work issues, and an inability to keep work preoccupations out of other domains of life (Siegrist, 1996). Resilient individuals may be more effective in coping with work issues and with maintaining a work/leisure balance. Although the effort/reward model is equally applicable to both men and women, perhaps the impact of over-commitment on the work/leisure balance may have a different meaning for women. In particular women with children may be more likely to have a greater nonpaid work load in terms of child care and domestic duties. Perhaps more resilient women are able to reduce the impact of stress from the working week (due to work commitments) on leisure time, and in this way may feel better able to cope with demands on their time during the weekends and evenings.

Resilience was a highly significant predictor of all affect and wellbeing questionnaire measures in the expected direction (a positive relationship with positive affect and negative relationships with depression, negative affect and sleep problems). Thus people with higher resilience report fewer physical and mental health problems. This is consistent with previous findings, since lower levels of depression, affective symptoms and somatisation in those with higher resilience have also been found in several other studies, as seen in Chapter 2.

The pattern of significant DRM measures showed a mixed profile. DRM positive affect was positively related to resilience for all time periods but DRM negative affect was only significantly related during the leisure day and evening. It was interesting that there were no significant relationships for DRM negative affect during the working day considering that the mean negative affect scores were higher on the work day than the leisure day. Perhaps the factors influencing negative affect during the work day (e.g. working conditions, workload etc), may have been different to those experienced during the leisure day and therefore show different relationships with resilience. Or it could be that those with higher resilience may be better able to deal with any accumulated negative affect from the working week that has carried over to the leisure day.

Previous research on the nature of the relationship between resilience and affect is complicated by the notion that although positive emotions are thought to underpin some of the active elements of resilience, it has also been reported that emotional flexibility during times of adversity helps resilient people cope with stress (Ong, et al., 2009). The relationship between resilience and daily positive affect found in this study adds weight to the formulation developed by Fredrickson et al (2003). However, the inconsistent relationship between resilience and daily negative affect suggests that a lack of negative affect is less important to resilience than the presence of positive affect.

4.4.1 The mediating influence of resilience

Resilience was found to be a significant mediator between the aggregate ‘stress load’ variable and the outcome measures of depression, sleep problems and PANAS measure of negative affect. Resilience also mediated between the individual psychosocial measures of reward, over-commitment and neighbourhood problems and the outcome measures of depression and PANAS negative affect, with a weak mediating effect between over-commitment and sleep problems. Resilience did not moderate between any stress and outcome variable, contrary to the findings of Ong et al (2009) in which resilience moderated between daily stress and negative affect the following day. A number of methodological differences could account for these inconsistent findings. Ong et al measured ego resilience rather than using the Resilience Scale and assessed daily stress and negative affect on consecutive days, whereas our study involved chronic stress and several different measures of affective state.

In this study, the effects of stress on depression, negative affect and sleep problems did not depend on level of resilience; instead as resilience increased the relationship between stress and affect and wellbeing outcomes was reduced in a graduated fashion, rather than eliminated. However, it should be noted that some of these relationships were weaker than others, such that adopting a stricter significance level to adjust for multiple tests would have resulted in non-significant results for several relationships (namely resilience as a mediator between over-commitment and each of the affective outcomes). Combining the stress indices resulted in a stronger correlation between stress load and resilience compared with the individual psychosocial stressors. This suggests that although the individual psychosocial stressors are related to resilience, a combination of stressors may augment these relationships. The cumulative stress measure in this study may be compared with the concept of allostatic load caused by the 'repeated hits' of multiple stressors (see Chapter 2). Resilience may help to reduce allostatic load by attenuating the effects of multiple stressors on affect and wellbeing outcomes.

However, the lack of mediation with daily affect measures suggests that resilience may temper the effects of stress on affect over a longer time period, rather than exerting an 'everyday' effect. Alternatively it may be due to the method of measurement. Perhaps daily measures of stress correspond more closely with daily affect measures, and differ conceptually from questionnaire measures of affect. There is evidence to suggest that retrospective global evaluations are not necessarily averages or amalgamations of experience over time, but are influenced by recent or momentary evaluations. For example, Redelmeier and Kahneman (1996) found that participants' retrospective ratings of overall pain during colonoscopy, were largely dependent on how they felt at the most painful point and at the end of the procedure, and that the actual duration of pain episodes over time was not taken into account. It is also possible that the impact of psychosocial adversity on experienced affect and recollected affect is different. For example, Knabe, Rätzel, Schöb and Weimann (2010) reported that despite differences in life satisfaction between employed and unemployed people, day to day experienced affect as assessed with the DRM did not differ.

Another possible explanation for this difference in findings could be due to common method variance among the questionnaire measures i.e. variance due to the method of measurement instead of the constructs the measures are supposed to test for (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). It could be that conditions present during questionnaire completion, such as individual differences in mood, may increase the likelihood that answers to different questionnaires could be in agreement. The potential for negative mood at time of testing to bias answers to other questionnaires is unlikely to be the main explanation, since resilience still remained a significant predictor of affect and wellbeing questionnaire outcomes despite the addition of negative affect to the regression models as a covariate.

The Resilience Scale was constructed using accounts of dealing with a major stressful event, so perhaps it does not apply so robustly to affect in everyday life. Resilience may exert influence on the ability to deal with the effects of the accumulation of stress or negative affect rather than with daily experiences. There is some evidence to support this idea; Pinquart (2009) found a significant association between daily hassles and resilience (as measured by the Resilience Scale) in adolescents, but only a partial and very weak buffering influence of resilience on the effects of daily hassles on psychological distress. Also, as Kahneman and Riis (2005) point out, evaluated well being and that experienced on a daily basis may differ, but it is the impact of these affect and wellbeing measures that is of interest. For example, Wirtz, Kruger, Napa Scollon, and Diener (2003), found differences in recalled enjoyment of a holiday compared with actual experience, but whether or not the participants said they would repeat the holiday depended on the recalled assessment. Perhaps resilience is a trait used to deal with the overall experience of stress over time (as seen in questionnaire measures) and that mechanisms used to deal with daily experience may be related to, but distinct from resilience as a concept (e.g. the use of individual coping mechanisms).

4.4.2 Limitations

Note: This section presents limitations relevant to the current study. Further general limitations of the Daytracker study can be found in Chapter 7.

The current study is limited to self-report measures in healthy, full time employed women, who were recruited from university campuses. A sample chosen from a different population might be more representative of working women in the UK. Also it would be interesting to compare findings from unemployed or very low income participants, and those with potentially high stress jobs such as emergency workers.

A design limitation of this study is that the 'leisure' evening in the DRM was on Friday, so although it marked the beginning of the weekend, it also immediately followed a working day. It was necessary to start the leisure assessment period on a Friday evening, since participants needed to be fitted with physiological monitoring devices in another aspect of the Daytracker study reported in Chapter 6. Although participants indicated that the monitoring days were relatively typical for them, additional monitoring days could have provided more robust estimates of daily affect measures.

The limitations of the cross-sectional design have already been noted. An additional issue in this regard is the application of moderation and mediation analyses to cross-sectional data, since such methods assume a temporal sequence between variables (Maxwell & Cole, 2007). The rationale of the current analysis is that both resilience and the stress exposures are presumed to be relatively enduring phenomena, so the measures obtained in the study may have reflected ongoing experience. As noted in the method, the variables presented in the mediation model here could be placed in a different order, but the current model seemed most likely based on previous research. However, a follow up study to assess longitudinal changes would be beneficial in testing the model over time.

4.4.3 Conclusion

The mediating effect of resilience on the impact of stress-related variables on negative affective and wellbeing outcomes is an important finding that supports the hypothesis that resilience has a protective role in resisting stress (Feder, et al., 2009). The study used measures of affective well-being in everyday life as well as standard retrospective assessments in a large sample of women. The role of resilience as a mediator was seen in particular stressor-wellbeing outcome pairs, but not in others. Most notably, resilience did not mediate between any of the stressors and the daily affect variables. The reason for the inconsistency of resilience as a mediator is not yet clear; one possibility is that resilience (as measured with the RS) is more relevant to more global measures of affect than to daily measures.

5 Resilience, depressive symptoms and cortisol in healthy working women

5.1 Introduction

The previous chapter provided evidence for the role of resilience as a mediator, suggesting that resilience may reduce the negative impact of stress on affect/wellbeing outcomes. Since stress influences both physical processes and psychological wellbeing, it seems reasonable to suggest that physiological processes relevant to both stress and health (such as cortisol) may also differ according to resilience. As discussed in Chapter 1, positive traits and states may be associated with reduced daily cortisol output, reduced CARs and steeper cortisol slopes (e.g. Lai, et al., 2005; Polk, et al., 2005; Steptoe, et al., 2007), though there are many inconsistencies in the literature. The associations between positive traits and reduced cortisol may help to explain the links between positive wellbeing and health. Despite the relevance of resilience to this area (because it is a positive trait related to stress), there has been little research into the relationship between cortisol and resilience.

The most relevant study to date examined the relationship between the CD-RISC measure of resilience and a single measure of waking salivary cortisol and dehydroepiandrosterone (or DHEA, another stress related steroid hormone) in 32 participants (Petros, et al., 2013). In this study, regressions adjusted for age and gender revealed that resilience had a significant positive relationship with DHEA, but there was no association with waking cortisol and DHEA/cortisol ratio. In addition, a small number of studies have investigated resilience and cortisol reactivity to stress. Mikolajczak, Roy, Luminet, & de Timary (2008) found that men with higher resilience scores (measured using the Resilience Scale for Adults), produced less cortisol just prior to stress tests compared to men with lower scores. This result was attributed to differences in anticipation of the stressor, because there were no differences in cortisol during the stress test or in recovery. A large study of cortisol reactivity in 5 year old children (N= 101), reported that children with low ego resiliency (a trait-like measure of resilience), had elevated cortisol levels during negative interactions with their parents, whereas children with higher ego resilience did not (Smeekens, Marianne Riksen-Walraven, & Van Bakel, 2007). However, the results of the latter study may not be applicable to adults because of age related changes in cortisol regulation (Kiess et al., 1995).

The relationship between resilience and cortisol regulation throughout the day among healthy adults in a naturalistic setting remains unknown. Additionally, women have been under-represented in this area of research. The current study therefore investigated the relationship between resilience and cortisol in a large community sample of healthy, working women from the London Daytracker study.

Since resilience is defined as the ability to flourish under stressful conditions, we reasoned that people with higher resilience may show lower total cortisol outputs, lower CARs and steeper cortisol slopes. This reasoning was based on previous studies reporting: i) inverse relationships between positive wellbeing and cortisol, and ii) positive relationships between stress and cortisol (summarised in Chapter 1). Because resilience is a positive trait associated with less perceived stress, cortisol levels will most likely be lower in people with higher resilience. However, it should be noted that some of the positive wellbeing and cortisol studies reported in Chapter 1 had conflicting results, so we may find different relationships with different measures of cortisol.

Using different cortisol measures (CAR, cortisol slope and total cortisol in these analyses) is also important because the mechanisms regulating the CAR and cortisol profile for the rest of the day are distinct and complex (see Chapter 1, section 1.4.2). For example the CAR is influenced by circadian rhythms including activity of the suprachiasmatic nucleus (SCN) which helps coordinate the sleep wake cycle, although the co-ordinating mechanisms are not fully understood (Buijs, Van Eden, Goncharuk, & Kalsbeek, 2003; Dickmeis, 2009). The CAR appears to be coordinated with the waking process, as is evident from the demonstration by Wilhelm et al (2007) that the rise in cortisol is steeper than can be accounted for by the diurnal cycle on its own, and from the fact that the CAR is not disturbed by repeated awakenings in the night (Dettenborn, Rosenloecher, & Kirschbaum, 2007).

One prominent theory about the function of the CAR is that it prepares the individual for the demands of the upcoming day (Powell & Schlotz, 2012). This may be the explanation of the well-documented difference between the CAR on work and leisure days (described below), and is consistent with evidence that the CAR is greater among people reporting worry or preoccupation with work (Chida & Steptoe, 2009). An intensive within-person study showed that feelings of threat, sadness and lack of control on the day before predicted a larger CAR on the following day (Adam, et al., 2006). Another finding that illustrates the importance of anticipation is the observation that patients with severe amnesia do not show any CAR or rise in cortisol after waking (Wolf, Fujiwara, Luwinski, Kirschbaum, & Markowitsch, 2005).

However, a range of other factors including genetic, physiological and psychological (e.g. the stress response) are also implicated in cortisol regulation. Stress is of particular importance because of its influence on the HPA axis therefore daily stress measures were also considered in the current analysis. Studies comparing perceived stress across work and leisure days show that both men and women report greater perceived stress during a work day compared with a leisure day (Evans & Steptoe, 2001; Kunz-

Ebrecht, Kirschbaum, Marmot, & Steptoe, 2004). Also, greater CARs have been reported on work days compared with leisure days; a factor that has been attributed to increased stress during the working week (Kunz-Ebrecht, et al., 2004; Schlotz, Hellhammer, Schulz, & Stone, 2004). Thus, any relationship between resilience and cortisol might be more apparent over a working than leisure day, since the demands on the individual may be greater, providing resilient traits with more scope to be adaptive.

We also assessed the relationship between depressive symptoms and cortisol, and intended to evaluate whether resilience was associated with cortisol independently of depressive symptoms. As discussed in Chapter 1 (section 1.4.2.1), major depression has been associated with increased cortisol production (Stetler & Miller, 2011). Depressive symptoms in healthy participants have been associated with flatter cortisol slopes (e.g. Knight, et al., 2010) and both increased and decreased CAR (for a review see Chida & Steptoe, 2009). High morning cortisol or a larger CAR predicts future depression, particularly among individuals at risk because of other factors such as elevated subclinical depressive symptoms or family history (Owens et al., 2014; Vrshek-Schallhorn et al., 2013). Studies of people with major depressive disorder who are in remission have shown that a larger CAR is associated with greater risk of relapse (Hardeveld et al., 2014). Thus, if there is an association between depressive symptoms and cortisol in this study it seems most likely that depression will be related to greater total cortisol, larger CAR and flatter cortisol slopes.

5.2 Method

The participants were 192 healthy working women with a mean age of 33.5 years (SD 9.03, range 21-61 years), from the UK Daytracker dataset. The number of participants was less than in Chapter 4 because cortisol data was missing from some participants; therefore they have been excluded from these analyses.

The participants were asked to collect saliva samples at the 7 collection times on each monitoring day: 1) 5pm, 2) bedtime, 3) waking, 4) 30 minutes after waking (‘waking+30’), 5) 10am, 6) 12pm and 7) 3pm. Whilst taking each sample, the participants completed the saliva sample diary which included the momentary stress ratings. EMA measures of stress were chosen in this study (instead of DRM measures) since they were more closely related to the timing of the cortisol sampling. The psychological measures included in this set of analyses were resilience and depression (CES-D).

5.2.1 Data analysis

The physical activity data from the Actiheart units was used to help validate the participant’s self-reported bedtime and waking times. Objective data was used where self-reported sleep and waking times were more than 10 minutes different from the Actiheart readings. Note that the Actiheart data cannot be used alone to provide sleep and waking times because these devices only measure movement and therefore need to be interpreted alongside self-report (i.e. people may be awake but resting in bed with little movement).

The cortisol data was used to calculate 3 measures of cortisol for each participant: total cortisol, cortisol awakening response (CAR) and cortisol slope. Total cortisol was calculated using the area under the curve with respect to ground (AUC_G) method (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003a). This method uses a formula to take into account individual measurements (from zero or the ‘ground’) and the time between each measurement. The formula for calculating AUC_G is as follows, where m_i represents an individual measurement, t_i the time distance between individual measurements, and n the total number of measurements:

$$AUC_G = \sum_{i-1}^{n-1} \frac{\left(m_{(i+1)} + m_i\right).t_i}{2}$$

All 7 samples for each day were required to calculate the total cortisol values, therefore participants with any missing samples were excluded from the calculations. There were only 4 participants for the work day with incomplete samples (3 had no samples at all) and 5 participants for the leisure day with incomplete samples (3 had no samples at all). Because there were only 3 participants with some but not all samples for each monitoring day (and therefore had missing total cortisol scores), it was unnecessary to impute missing values. Logged values (using natural log), were used as the total cortisol scores were not normally distributed.

Cortisol awakening response (in nmol/l) was calculated as the cortisol increase (or CAR_i), by subtracting the waking value from the waking+30 value. Participants with a delay of greater than 15 minutes between waking and taking the waking sample were not included in the CAR calculations. Such delays in taking the waking sample can lead to misleading results, either because the CAR has already started or cortisol levels have started to decline after reaching peak values (Dockray, Bhattacharyya, Molloy, & Steptoe, 2008; Edwards, et al., 2001; Schmidt-Reinwald, et al., 1999).

Finally, cortisol slope was calculated as the regression slope of the daily change in cortisol concentration from waking to 3pm, across each day for each participant. As the 5pm and bedtime samples were collected during the previous day, they were not included in the cortisol slope calculations. A minimum of 4 samples (out of 5) across each monitoring day was required to calculate the cortisol slope (so that there was at least one afternoon sample). As in the total cortisol calculations, there were only 3 participants with insufficient samples; therefore it was unnecessary to impute missing values. All other participants with missing data had no samples across each monitoring day (in which case they were excluded from the study anyway). The slope was calculated by regressing concentrations against the time intervals between samples, and the values are in nmol/l/min.

5.2.2 Statistical analysis

Bivariate correlations, partial correlations, t-tests or analyses of variance were conducted as appropriate to assess whether resilience was associated with demographic measures, to explore relationships between resilience and depression, and to explore relationships between daily stress and resilience.

A series of multiple linear regression analyses were used to assess relationships between: i) resilience and cortisol, ii) depression and cortisol and iii) daily stress and cortisol (where cortisol was the DV in all cases). There was a separate model for each of the 3 measures of cortisol on each of the monitoring days (making a total of 6 analyses each for resilience, depression and daily stress). Each model was adjusted for age, BMI, smoking status, parental status and time of waking as these factors have been found to be independently related to cortisol regulation (Clow, Hucklebridge, & Thorn, 2010; Daniel et al., 2006; Fraser et al., 1999; Hansen, Garde, & Persson, 2008; Kirschbaum, Wüst, & Strasburger, 1992; Luecken et al., 1997; Rohleder & Kirschbaum, 2006; Van Cauter, et al., 1996). If there were significant relationships between resilience and cortisol, further analyses were planned to assess the independence of these relationships from daily stress and depression. Results are presented as standardized betas with standard errors. The absence of multicollinearity was established before analysis.

The work and leisure days were analysed separately following previous studies suggesting cortisol regulation may differ across a work day compared with a leisure day (Kunz-Ebrecht, et al., 2004; Schlotz, et al., 2004). There were also unequal numbers of participants for each monitoring day and combining the two monitoring days in a multivariate analysis resulted in a loss of power, due to a smaller number of participants with results from both monitoring days. For comparison, multivariate analyses across the two days can be found in appendix 3. The results of the multivariate analyses were similar to those derived from the separate analyses, so only the latter are shown in this chapter.

5.3 Results

The demographic characteristics of the participants can be seen in Table 5.1. They are slightly different to those in chapter 4 because 7 people out of the 199 recruited participants did not have acceptable cortisol data. The mean age of the women in the study was 33.5 years (SD 9.03), with an average 41 hours spent working per week and almost equal numbers of married and single/divorced participants. As in chapter 4, the majority of the women was white European, educated to degree level or higher, did not have children and earned a personal income of £25, 000 to £35,000.

Resilience was significantly related to income, with those in the higher income group reporting greater mean resilience (64.8 ±10.4), compared to those in the middle (59.3 ±10.1) and lower (59.0 ±11.6) income groups ($F(2, 186)= 4.588$, $p= 0.011$). When age was included as a covariate, these differences in income remained significant. Participants with children had higher resilience scores than those without (means 65.6 ±10.2 and 59.5 ±10.8 respectively, $t= -2.727$, $p= 0.007$). In multiple regression on resilience scores, personal income ($\beta= 0.206$, SE= 0.077, $p= 0.008$), parental status ($\beta= 0.252$, SE= 0.081, $p= 0.002$) and age ($\beta= -0.221$, SE= 0.086, $p= 0.011$), were independent predictors. Resilience was not related to education, ethnicity, marital status, or hours of work. Daily stress was significantly greater on the work day (2.18 ±0.820) compared with the leisure day (1.63 ±0.678, $t= 8.115$, $p< 0.001$).

Table 5.1: Demographic and psychological characteristics of the sample

Characteristic	**N (%)**
Education	
Less than degree	70 (36.8)
Degree or higher	120 (63.2)
Marital status	
Single/divorced	92 (49.2)
Married	95 (50.8)
Has children	
Yes	27 (14.2)
No	163 (85.8)
Ethnicity	
White European	154 (81.1)
Other	36 (18.9)
Personal income	
<£25,000	62 (32.6)
£25,000-£35,000	86 (45.3)
>£35,000	42 (22.1)
	Mean (SD)
Age, yrs	33.5 (9.03)
Hours of work	
Hours of work onsite	37.8 (5.74)
Total hours of work	41.0 (7.11)
Resilience	60.4 (10.9)
Depression	12.2 (8.72)
Daily stress (EMA)	
Work day	2.18 (.820)
Leisure day	1.63 (.678)

Key: N = number, SD = standard deviation

5.3.1 Cortisol

Mean cortisol concentration (nmol/l), throughout the work and leisure day are shown in Figure 5.2. These cortisol profiles show a typical pattern for healthy adults, reaching the peak value 30 minutes after waking and then declining throughout the rest of the day. The mean waking time was 6.55am (±52 minutes) on the work day and 7.58am (±1 hour and 22 minutes) on the leisure day.

A repeated measures ANOVA showed a significant interaction between time and monitoring day ($F(3.31, 351)= 6.631$, $p \leq 0.001$) and a main effect of time ($F(3.31, 23844)= 450.7$, $p \leq 0.001$). According to Bonferroni corrected *post hoc* t-tests, there was a significantly greater waking+30 value during the work day (21.3 ±12.0) compared with the leisure day (18.2 ±9.17, $t= 3.289$, $p= 0.001$), and a greater mean cortisol concentration at 12pm on the leisure day (7.81 ±4.34) than on the work day (6.80 ±3.86, $t= -2.603$, $p= 0.010$). The difference in waking value between the work day (15.6 ±8.40) and the leisure day was not significant (14.2 ±7.73, $t= 1.861$, $p= 0.064$). Correlations across the work and leisure day for each cortisol sample showed weak but significant positive relationships: waking ($r= 0.251$, $p= 0.001$), waking+30 ($r= 0.289$, $p< 0.001$), 10am ($r= 0.274$, $p< 0.001$), 12pm ($r= 0.194$, $p= 0.009$), 3pm ($r= 0.189$, $p= 0.011$), 5pm ($r= 0.291$, $p< 0.001$) and bedtime ($r= 0.232$, $p= 0.002$).

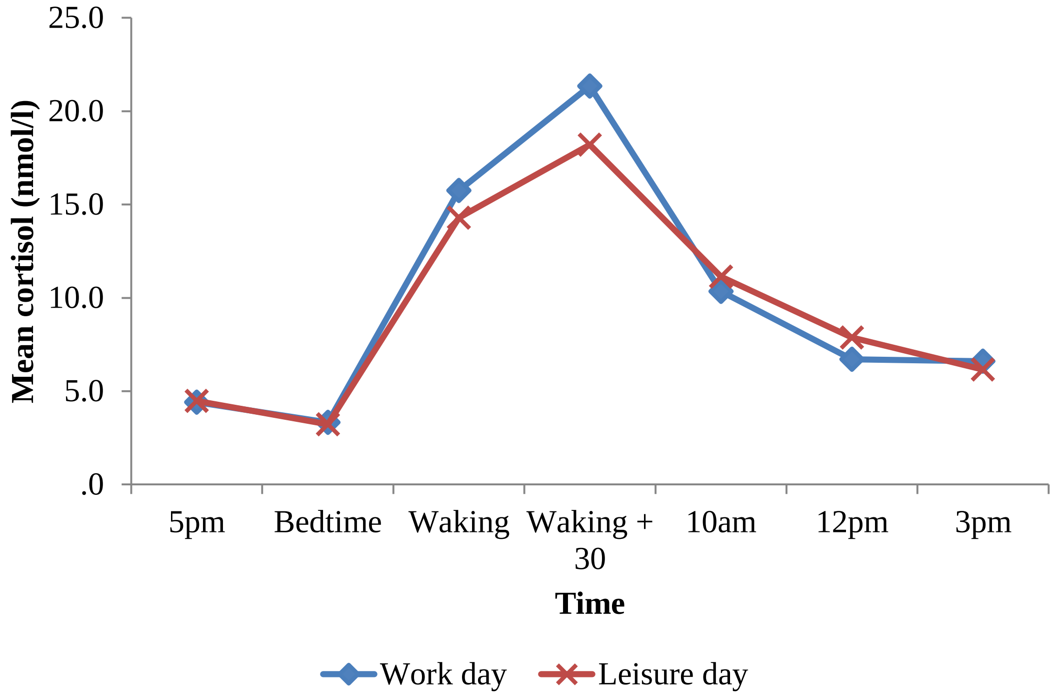


Figure 5.2: Mean cortisol concentrations across the work and leisure day

Mean (SD) total cortisol, CAR and cortisol slope values for the work and leisure day can be seen in Table 5.3. Total cortisol during the work day was significantly greater than during the leisure day ($t= 5.193$, $p< 0.001$). CAR was also greater during the work day compared with the leisure day, but this difference was not significant ($t= 1.711$, $p= 0.089$). There was also no significant difference between work and leisure day cortisol slope ($t= -0.230$, $p= 0.818$). A correlation matrix of all the variables in this study is shown in Table 5.4. Considering the correlations between the work and leisure day for each cortisol measure, only total cortisol during the work day was correlated with total cortisol on the leisure day ($r= 0.413$, $p< 0.001$). Total cortisol on the work day was correlated with work day CAR and cortisol slope, and total cortisol on the leisure day was correlated with leisure day CAR and cortisol slope ($p= 0.009$ to $p< 0.001$). Work day CAR was not associated with work day cortisol slope, likewise leisure day CAR was not associated with leisure day cortisol slope.

Table 5.3: Mean (SD) total cortisol, cortisol awakening response (CAR) and cortisol slope for the work and leisure days

	Work day			Leisure day		
Cortisol variable	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Total cortisol (AUC_G, log)	186	7.12	.417	181	6.97**	.381
CAR (nmol/l)	155	6.49	9.31	151	5.18	7.71
Cortisol slope (nmol/l/min)	192	.019	.015	188	.020	.018

**significant difference between work and leisure day ($p<0.001$)

Menstrual phase was not associated with any cortisol measure during the work day or the leisure day (significance levels ranged from p= 0.066 to p= 0.951). There were no differences in cortisol output related to reports of taking exercise, taking medication, having caffeine, drinking alcohol, brushing teeth or eating a meal in the 30 minutes before each sample (significance levels ranged from p= 0.066 to p= 0.975). One minor difference emerged in people who smoked in the period before saliva collection at 3pm. People who had smoked prior to this sample had a smaller mean cortisol volume (3.74 ±0.936), compared to those who had not (6.11 ±3.51). This difference was significant according to a Bonferroni corrected t-test ($t= 5.71$, $p\leq 0.001$). There were no significant differences for smoking prior to any other sample. Thus, we did not adjust regression models for any other variables than the planned covariates (age, BMI, smoking status, parental status and waking time).

Table 5.4: A correlation matrix of all the psychological and cortisol variables in this study (adjusted for age, BMI, smoking status and parental status)

Variable	2	3	4	5	6	7	8	9	10
1. Resilience	-.571***	-.047	-.245**	-.097	.011	-.027	.035	-.010	.131
2. Depression	_	.163	.361***	.019	.003	-.031	-.012	-.086	-.145
3. Daily stress work day	_	_	.364***	.116	-.041	.019	-.021	-.009	.127
4. Daily stress leisure day	_	_	_	.150	.161	.110	-.033	.117	.035
5. Total cortisol work day	_	_	_	_	.413***	.644***	.020	.425***	.173
6. Total cortisol leisure day	_	_	_	_	_	.233**	.376***	.347***	.342***
7. CAR work day	_	_	_	_	_	_	-.138	.065	.201*
8. CAR leisure day	_	_	_	_	_	_	_	.127	-.108
9. Cortisol slope work day	_	_	_	_	_	_	_	_	.147
10. Cortisol slope leisure	_	_	_	_	_	_	_	_	_

*p<0.05, **p<0.01, ***p<0.001

5.3.2 Resilience, depression, daily stress and cortisol

The correlations between the psychological and cortisol variables can be seen in Table 5.4 (adjusted for age, BMI, smoking status and parental status). Resilience and depression were moderately negatively correlated ($r = -0.592$, $p \leq 0.001$). Resilience had a weak negative correlation with stress on the leisure day ($r= -0.192$, $p= 0.016$) but not on the work day, whereas depression was positively associated with stress on both days (work day: $r= 0.190$, $p= 0.017$, leisure day: $r= 0.344$, $p<0.001$). Work day and leisure day stress were also positively correlated ($r= 0.269$, $p<0.001$). There were no significant correlations between any of the psychological and cortisol variables.

Following a series of regression analyses (adjusted for age, BMI, smoking status, parental status and waking time) resilience was not related to any of the cortisol measures during the work day or the leisure day (see Table 5.5). To check whether the same results were found for resilience and leisure day cortisol slope with a regression model that did not include parental status and time of waking, the analysis was repeated with adjustments for age, BMI and smoking status only. The association between resilience and leisure day cortisol slope was just significant in the less cautious model ($\beta= 0.151$, SE= 0.076, $p= 0.050$).

Depression was significantly related to cortisol slope during the leisure day ($\beta= -0.185$, SE= 0.079, $p= 0.020$), with higher depression being associated with a flatter cortisol slope. No other associations between depression and cortisol measures were significant ($p= 0.202$ to $p= 0.959$). Daily stress was also not related to any of the cortisol measures ($p= 0.080$ to $p= 0.964$). Due to the lack of significant findings for resilience, no further analyses were conducted.

Table 5.5: Regression analyses of resilience on cortisol measures (DV) for the work and leisure day (adjusted for age, BMI, smoking status, parental status and waking time)

	Work day				Leisure day			
Cortisol variable (DV)	**β**	**SE**	**p**	**R^2**	**β**	**SE**	**p**	**R^2**
Total cortisol (AUC_G)	-.003	.082	.969	.057	.007	.082	.933	.072
Cortisol awakening response (CAR)	.005	.085	.955	.015	.001	.084	.986	.038
Cortisol slope	.090	.082	.278	.038	.151	.081	.065	.053

Key: β = standardized regression coefficient for resilience as an independent variable, SE = standard error

5.4 Discussion

The results of this study did not provide evidence for relationships between resilience and cortisol. The relationship between resilience and leisure day cortisol slope approached significance (p= 0.065), and was marginally significant (p= 0.05) in a regression model that adjusted for age, BMI and smoking status only. People with greater resilience were hypothesised to have lower total cortisol, lower CAR and steeper cortisol slopes. Additionally, the associations were expected to be stronger during the work day since perceived stress tends to be higher during work periods compared with leisure periods (e.g. Kunz-Ebrecht, et al., 2004). None of the hypotheses for resilience were met. The only significant finding in the study was for depression and leisure day slope where people reporting more depressive symptoms had flatter cortisol slopes.

Despite having a much larger sample size and collecting a greater number of cortisol samples, the results of this study are similar to the findings of Petros et al (2013) who reported no association between resilience and waking cortisol in 32 participants. The current results are inconsistent with previous research into cortisol reactivity where people with higher resilience showed less cortisol reactivity under stressful conditions (Mikolajczak, et al., 2008; Smeekens, et al., 2007). Perhaps we might have had similar results if we had also assessed cortisol reactivity to acute mental stress in the laboratory, but it seems that under daily, naturalistic conditions, the association between resilience and cortisol is not apparent.

It is interesting that the only significant relationship for depression and cortisol slope was seen on the leisure day, despite greater levels of reported daily stress on the work day. The relationship between greater self-reported depression and flatter cortisol slopes during the leisure day is consistent with previous studies in this area (e.g. Knight, et al., 2010; Sjögren, et al., 2006). However, because a similar result was not found during the work day (and there were no other significant results) this finding needs to be interpreted with caution. The relationship was not particularly strong ($p= .022$) so it is possible that the result was found by chance. If a more stringent significance level was adopted (to reduce the chance of type 1 error), the association would no longer be significant. It could be co-incidental that the relationship between resilience and leisure day cortisol slope also approached significance, or else there may be something specific to the leisure day underlying these trends. For example, perhaps people reporting greater depressed mood were less able to cope with any negative effects of stress during the working week which were carried over to the weekend. Or it could be that other factors e.g. overcommitment at work were more important to the work day cortisol slope than depression or resilience.

A reason for the largely non-significant results here could be related to cortisol regulation. There is considerable intra- and inter-individual variation in diurnal cortisol profiles (e.g. Hansen, et al., 2008; Stone et al., 2001) because there are many factors which influence cortisol, as previously mentioned. The analyses in this chapter were adjusted for a number of relevant covariates. Additionally the influence of menstrual phase and behavioural factors prior to sample collection (e.g. exercise) was considered. It is likely that other unmeasured factors will have strong influence over cortisol regulation. This makes demonstrating the links between psychological variables and cortisol difficult since the relationships can often be subtle and fleeting.

One way to help remedy this problem would be to increase the number of participants so that any subtle associations are more apparent. It might be useful to measure cortisol on a greater number of monitoring days, particularly consecutive days. For example, with consecutive monitoring days it would be possible to demonstrate the influence of daily stress on next day CAR as in the study by Adam et al (2006), so that the role of resilience in attenuating these relationships could be tested. Alternatively, resilience may be involved in longer term adaptive processes which may not necessarily be seen on a day to day basis, so perhaps longitudinal cortisol and stress assessment would be more fruitful. However little is known about whether daily cortisol rhythms are stable within individuals over periods of months or years (Stone, et al., 2001).

In summary, the results of this study were largely inconsistent with the hypotheses. Perhaps resilience is simply not related to cortisol. The lack of previous research in this area could reflect a publication bias towards significant findings and perhaps other researchers have also found null results. Alternatively, resilience may be associated with cortisol via some other indirect mechanism, which has not been measured here. The analyses of this study treat resilience as a predictor of cortisol measures, but the relationship between resilience and cortisol regulation may be the other way around, or even bi-directional.

5.4.1 Limitations

A limitation of this study was that although cortisol sampling took place within a 24 hour period, the first sample was at 5pm and the last sample was at 3pm the following day. For this reason the 5pm and bedtime samples were not included in the cortisol slope calculations. Future studies would benefit from having cortisol samples collected during the same day. Also, as previously mentioned, a greater number of monitoring days would have been beneficial as this would allow for circadian rhythms in cortisol expression to be more fully understood (Hellhammer et al., 2007). There were no objective measures of cortisol sample timing, and this would have made analysis of the CAR more precise (Smyth, et al., 2013).

Further general limitations of cortisol assessment are discussed in Chapter 7, section 7.2.4.

5.4.2 Conclusion

Relationships between resilience and cortisol in this study were not significant. The only significant result suggested that depression was associated with flatter cortisol slopes during the leisure day. Replication of the study with a greater number of participants and/or a greater number of monitoring days might be able to establish reasons for the lack of associations, or may help improve the cortisol slope models.

6 Resilience, physical activity and heart rate variability

6.1 Introduction

Chapter 5 examined associations between resilience and cortisol as a biological correlate of stress and health. This chapter seeks to further explore associations between resilience and another biological correlate: heart rate variability (HRV). Frequency measures of HRV were introduced in Chapter 1 (section 1.4.4) as an indicator of sympathetic and parasympathetic nervous influences on the heart. HRV correlates both with stress and health outcomes, similarly to cortisol. The current chapter also expands the analyses to include measures of physical activity as a potential linking factor between resilience and HRV.

6.1.1 Heart rate variability (HRV) and resilience

Chapter 1 presented a small number of studies which suggested a modest association between greater positive wellbeing and increased HRV, in patients with coronary artery disease (either diagnosed or suspected), and in healthy samples (Bacon, et al., 2004; Bhattacharyya, et al., 2008; Geisler, et al., 2010). Both acute and chronic stress have been associated with changes in HRV suggesting an increase in sympathetic and/or reduction in parasympathetic nervous influence as evidenced by reduced HF-HRV and increased LF/HF ratio (e.g. Berntson & Cacioppo, 2007; Clays, et al., 2011; Hintsanen, et al., 2007). Reduced HRV was associated with poorer health outcomes, such as an increased risk of CHD (Dekker, et al., 2000). Therefore, links between resilience (as a positive trait inferring ability to withstand stress) and HRV may be particularly relevant to understanding links between positive wellbeing and cardiovascular health.

To date, there has been little research into resilience and HRV. In a study of cardiac patients (Hallas, et al., 2003), described in Chapter 2, dispositional resilience was positively correlated with time-domain measures of HRV both pre- and post-operation. However, these correlations were not statistically significant, possibly due to a small sample size (N=22). A recent laboratory study of ego resilience in 50 male army personnel found that higher resilience was associated with higher resting RMSSD measures of HRV assessed over 5 minutes (Souza et al., 2013). The study also investigated resilience and the related area of cardiovascular reactivity and recovery following a variation of the Trier Social Stress Test (TSST). Following the speech stressor element of the TSST, men with higher resilience had increased RMSSD reactivity and recovery. Increased heart rate reactivity and recovery were also reported in men with higher resilience following the arithmetic-based stressor. These results suggest that men with higher resilience had more efficient recovery after stress, but also greater RMSSD-HRV during reactivity to stress (implying greater parasympathetic nervous influence on the heart).

A similar study in undergraduate students, found that people with high ego resilience or high vagal tone (greater HF-HRV) had reduced heart acceleration (better recovery) after a speech stress test (Souza et al., 2007). In contrast to Souza et al (2013), resilience and vagal tone were not significantly related (over a 2 minute recording at rest). However, resilience and vagal tone did interact synergistically in improving cardiac recovery time; participants with both high resilience and high vagal tone showed better cardiac recovery compared to participants with just one of these attributes. These laboratory stress studies are also in line with an earlier study by Tugade and Fredrickson (2004), mentioned in Chapter 1, which suggested that more resilient individuals showed better cardiac recovery following negative emotional arousal.

Thus, evidence to date suggests there could be an association between resilience and HRV (although the results are mixed) and that resilience may reduce the impact of stressful or negative episodes on cardiac recovery in laboratory studies of acute stress. The positive correlation between RMSSD-HRV and resilience in male soldiers (Souza, et al., 2013) and the similar (but non-significant) relationship in cardiac patients (Hallas, et al., 2003), seem promising. However, in both cases the findings are limited to specific populations, to RMSSD measures of HRV and the only significant results were from a 2 minute recording of HRV at rest under laboratory conditions (in Souza, et al., 2013). Although short recordings of HRV are related to 24 hour recordings, the correlation between the two is modest (Min, Min, Paek, Cho, & Son, 2008). Therefore a single, brief recording of HRV in the lab may not be representative of naturalistic measures across the day.

The relationship between resilience and cardiac activity in daily life in healthy women remains to be determined. The current study provides a naturalistic setting in which to study HRV and its association with resilience, which may help to provide a health-relevant understanding of resilience and biology links. Since resilience is especially relevant to coping with stress, we reasoned that any relationship with HRV would be greater during periods of increased stress. As mentioned in Chapter 5, perceived stress tends to be greater during a work day compared with a non-work day (Evans & Steptoe, 2001; Kunz-Ebrecht, et al., 2004). Heart rate tends to be greater during the work day compared to non-working day, in studies involving both sexes and in female workers specifically (Evans & Steptoe, 2001; Goldstein, Shapiro, Chicz-DeMet, & Guthrie, 1999). Additionally, Loerbroks et al (2010) reported that RMSSD measures of HRV were lower during the work day compared with the leisure day in younger workers. Therefore HRV may also differ between a work and leisure day.

Because increased heart rate and lower HRV have been associated with stress, we reasoned that people with higher resilience may show an attenuated stress response marked by lower heart rate and greater HRV. Since there may be differences in both perceived stress and cardiac activity when comparing a work and leisure day, any relationship between resilience and HRV may be more pronounced during a work day (when stress is likely to be greater). The measurement of factors such as physical activity may provide additional insight into potential indirect pathways between resilience and HRV.

6.1.2 Physical activity and resilience

Resilience may also impact on physical health risk through linkage with protective health behaviours such as regular physical activity. Regular physical activity is associated with reduced heart rate and increased HRV through increased parasympathetic control (see Sandercock, Bromley, & Brodie, 2005, for a meta-analysis). These effects may contribute to the impact of exercise on cardiac health. However, the literature relating resilience with regular physical activity is limited. A couple of studies in elderly participants showed that more resilient individuals tended to spend longer exercising (Resnick & Inguito, 2011), and that people with high resilience were more likely to take moderate to high frequency exercise (Perna, et al., 2011). Resilience was found to influence exercise indirectly through negative outcome expectations among elders (Resnick & D'Adamo, 2011). Additionally, higher resilience has been associated with taking regular exercise in postmenopausal women (Pérez-López, et al., 2014).

Resilience therefore appears to be a protective psychological process relevant to the stress and health link, while physical activity is a protective health behaviour. Since there is some evidence to suggest that higher resilience is associated with greater amounts of physical activity and that regular physical activity may increase HRV, this could be a pathway linking resilience with HRV. Therefore, higher resilience is hypothesised to be associated with greater self-reported physical activity and physical activity might mediate the relationship between resilience and HRV.

An additional consideration is physical activity at the time of HRV monitoring. Cardiac activity is closely linked to concurrent physical activity; heart rate tends to increase and HRV is reduced during physical activity due to changes in sympathetic and parasympathetic control (Bernardi, Valle, Coco, Calciati, & Sleight, 1996; Iellamo, 2001). Paradoxically, therefore, if resilient people were more active during the monitoring period, resilience would be associated with lower rather than higher HRV. Self-reported physical activity assesses the frequency and intensity of regular exercise, and may not be reflected in differential activity levels during the monitoring period. We therefore assessed concurrent objective activity as well as habitual self-reported activity levels.

6.2 Method

Participants were 195 healthy working women from the Hungarian Daytracker dataset. As outlined in Chapter 3, the Hungarian dataset was used in this analysis because the heart rate data were of better quality compared to the British study (where equipment malfunction and missing data reduced the amount of useable results). The mean age was 37.4 years (SD 10.6) with a range of 21-65 years.

Data from the Actiheart monitors was used to assess heart rate and objective physical activity during the work and leisure daytime and evening periods. The Day Reconstruction Method (DRM, Kahneman, et al., 2004), was used to determine participant assessments of daily stress. Questionnaire measures of resilience and self reported physical activity (Marmot, et al., 1991) were also included in this study.

6.2.1 Data analysis

DRM stress. Following the same method as described in Chapter 4, composite stress measures were calculated as the mean rating across the 3 stress related scales (feeling hassled, feeling criticised and frustration) which were then averaged over the work and leisure periods (see Table 4.2 in chapter 4).

Heart rate variability and activity. Raw data from the Actiheart units was downloaded, examined for outliers and corrected for artefacts using the Actiheart software 'Autoclean' function, as described in the User Manual (CamNTech, 2010). The Autoclean function searches for anomalous data (e.g. heart rate of less than 30 BPM) and compares suspect results with means across the previous 4 minutes. Data points are then recovered if possible using calculated heart rates based on stored minimum and maximum inter-beat-intervals (IBIs) across each minute. Values that could not be recovered by the software were set to zero and interpolation was used to fill any gaps of less than 5 minutes where there were zero values.

The N-N interval record from the single channel recording was segmented into 5 minute periods, from which mean heart rate, HF-HRV (0.15 to 0.40 Hz), LF-HRV (0.04 to 0.15 Hz) and LF/HF ratio were computed using Kubios HRV analysis software (Niskanen, Tarvainen, Ranta-aho, & Karjalainen, 2004). These periods were then combined for the day and evening time periods for the work and leisure day separately, making a total of 4 time periods. The evening period was measured first as it began at the start of the monitoring period at 5pm after work until bedtime, followed by the day period from waking to 5pm the next day.

Thus, there were potentially 4 values for each participant. Due to equipment malfunction and/or insufficient data, not all participants had HRV data for every time period. Therefore, the number of participants with sufficient HRV results during each time period were as follows; work day N=174, work evening N=195, leisure day N= 170 and leisure evening N=189.

Mean physical activity was calculated from accelerometers across the same periods in counts per minute. The original units of HRV were ms^2, but because of skewed distributions, logged values of the HRV and activity measures were used in statistical analysis.

6.2.2 Statistical analysis

Bivariate correlations, t-tests or analyses of variance were conducted to assess whether resilience was associated with any demographic variables. Differences in mean heart rate measures and objective activity were assessed using t-tests. Associations between objective activity and heart rate measures were further explored using regression analysis.

The associations between resilience, heart rate and HRV were analysed using linear regressions adjusting for age, marital status, BMI and smoking status. Resilience was regressed on heart rate, HF, LF and LF/HF ratio measures for each time period separately (work day, work evening, leisure day and leisure evening). Three models were tested. In model 1, age, marital status, BMI and smoking status were included as covariates, since these factors have been found to be independently related to HRV (Rajendra Acharya, et al., 2006; Randall, Bhattacharyya, & Steptoe, 2009). Model 2 added objective physical activity for the relevant time period, while self-reported physical activity was added in Model 3. Results are presented as standardized betas with standard errors. The absence of multicollinearity was checked before commencing the regression analyses.

As in Chapter 5, the days were analysed separately following previous research suggesting differences in heart rate measures between work and leisure periods (Evans & Steptoe, 2001; Goldstein, et al., 1999; Loerbroks, et al., 2010), and to avoid loss of power due to smaller numbers of participants with complete data for both days. Additionally, a multivariate design would have been unsuitable for models 2 and 3, which were adjusted for concurrent objective activity. However, the results of multivariate analyses for model 1 are shown in appendix 4 for comparison.

Resilience was also regressed on daily stress and self-reported physical activity. If both resilience and self-reported physical activity were significantly associated with HRV, further analyses were planned to test whether self-reported physical activity mediated between resilience and HRV following the same method as described in Chapter 4. The logic for self-reported physical activity as a mediator was based on previous research which suggested resilience is associated with physical activity and physical activity is associated with HRV (see introduction). Therefore if resilience is associated with HRV, then physical activity may provide an indirect path between resilience and HRV.

6.3 Results

The demographic characteristics and health behaviours of the research sample are shown in Table 6.1. The mean age was 37.4 years and the majority of the participants was educated to degree level or higher, did not have children and earned a personal income of between HUK 90,000 to HUK 130,000 per month (approx. £250-365). There were roughly equal numbers of married and single/divorced participants. Self-reported physical activity varied widely, but around half the participants reported no vigorous activity at all. Only a small number of participants (16.8%) were smokers.

Resilience scores averaged 65.9 ±12.1, and ranged from 31 to 90. In multiple regression on resilience scores, being married (β= 0.136, SE= 0.070, p= 0.054) and older age (β= 0.211, SE= 0.070, p= 0.003) were independently associated with greater resilience. Participants with children were more resilient than those without (means 68.1 ±11.4 and 64.3 ±12.4 respectively, t= -2.185, p= 0.030), but parental status was not significantly related to resilience in a regression with age and marital status. Resilience was not related to education, personal income, or hours of work.

Table 6.1: Demographic characteristics and health behaviours of the sample

Demographic & work hours	Mean (SD)
Age, yrs	37.4 (10.6)
Hours of work	
Hrs work onsite	39.6 (9.58)
Total hrs work	54.1 (15.3)
	N (%)
Education	
Less than degree	73 (37.6)
Degree or higher	121 (62.4)
Marital status	
Single/divorced	95 (49.0)
Married	99 (51.0)
Has children	
Yes	79 (40.7)
No	115 (59.3)
*Personal income**	
<HUK 90k	44 (22.8)
HUK 90-130k	93 (48.2)
>HUK 130k	56 (29.0)

* per month

Health behaviour	N (%)
Smoking status	
Smoker	32 (16.8)
Non smoker	159 (83.2)
Moderate exercise	
Never	27 (14.2)
1-3 times per month	68 (35.6)
1-2 times per week	69 (36.1)
3+ times per week	27 (14.1)
Vigorous exercise	
Never	92 (47.8)
1-3 times per month	51 (26.6)
1-2 times per week	36 (18.8)
3+ times per week	13 (6.80)
Total exercise score (moderate + vigorous)	
0	23 (12.2)
1	40 (21.2)
2	44 (23.3)
3	38 (20.1)
4	28 (14.8)
5	12 (6.30)
6	4 (2.10)

6.3.1 Objective physical activity, HRV and daily stress

Mean heart rate, HRV, objective physical activity and mean daily stress ratings are shown in Table 6.2. Heart rate, HF, LF, objective physical activity and daily stress were significantly higher on the work day compared with the work evening ($p = 0.024$ to <0.001). Similarly heart rate, HF, LF, objective physical activity and daily stress were greater during the leisure day compared with the leisure evening ($p= 0.015$ to < 0.001). Mean LF/HF ratio was greater on the work day than the leisure day ($t= 2.01$, $p= 0.047$). Likewise, objective physical activity and daily stress were significantly greater on the work day compared with the leisure day (activity: $t= 2.39$, $p= 0.018$, daily stress: $t= 6.81$, $p< 0.001$). There were no significant differences in HF and LF between the work day and leisure day and for any of the heart rate, objective physical activity and daily stress measures between the work and leisure evenings.

Table 6.2: Mean (SD) heart rate, HRV, objective physical activity and daily stress measures for the work and leisure day and evenings

	Time period			
	Work day	**Work evening**	**Leisure day**	**Leisure evening**
Heart rate (BPM)	$85.2\ (10.3)_{a}$	$81.5\ (9.57)_{a**}$	$84.8\ (10.3)_{b}$	$80.4\ (10.3)_{b**}$
High Frequency (log)	$6.43\ (.829)_{a}$	$6.34\ (.846)_{a*}$	$6.51\ (.741)_{b}$	$6.38\ (.802)_{b*}$
Low Frequency (log)	$7.23\ (.609)_{a}$	$7.08\ (.639)_{a**}$	$7.25\ (.557)_{b}$	$7.13\ (.679)_{b*}$
LF/HF ratio (log)	$1.13\ (.093)_{c}$	1.13 (.094)	$1.12\ (.087)_{c*}$	1.12 (.077)
Activity (log)	$5.44\ (.509)_{a,c}$	$4.93\ (.713)_{a**}$	$5.29\ (.677)_{b,c*}$	$4.90\ (.804)_{b**}$
DRM stress rating	$2.03\ (.865)_{a,c}$	$1.83\ (.785)_{a*}$	$1.55\ (.712)_{b,c**}$	$1.78\ (.875)_{b**}$

Key: subscript letters denote significant differences between work day and work evening (a), leisure day and leisure evening (b) and between work day and leisure day (c), *p<0.05, **p<0.001

Regression analyses (adjusted for age, marital status, BMI and smoking status) revealed that objective physical activity was significantly associated with heart rate for all corresponding time periods: thus work day activity was related to heart rate during the work day (β= 0.304, SE= 0.070, $p < 0.001$) and activity on the evening of the work day was related to heart rate during that period (β= 0.368, SE= 0.069, $p < 0.001$). Leisure day and evening activity were associated with leisure day and evening heart rate respectively (day, β= 0.257, SE= 0.072, $p < 0.001$; evening, β= 0.383, SE= 0.067, $p < 0.001$). Objective physical activity was significantly associated with HF and LF/HF ratio measures during the work day (HF, β= -0.193, SE= 0.078, p= 0.015; LF/HF, β= 0.198, SE= 0.080, p= 0.014), but not during other periods. Higher objective physical activity was associated with increased heart rate for all time periods, decreased HF-HRV and increased LF/HF ratio during the work day. Higher resilience was also associated with lower levels of perceived daily stress for both the work period (day, β= -0.318, SE= 0.071, $p < 0.001$; evening, β= -0.268, SE= 0.073, $p < 0.001$) and leisure period (day, β= -0.249, SE= 0.075, p= 0.001; evening, β= -0.241, SE=0.073, p=0.001).

In summary, the significant relationships here were as follows:

1. Heart rate, HF-HRV, LF-HRV, objective physical activity and daily stress were greater during the day compared to the evening (for both work and leisure periods).
2. LF/HF ratio, objective physical activity and daily stress were greater on the work day compared to the leisure day.
3. Greater objective physical activity was associated with i) increased heart rate for all time periods, ii) decreased HF-HRV during the work day, and iii) increased LF/HF ratio during the work day.
4. Higher resilience was associated with less daily stress on both the work and leisure day.

6.3.2 Resilience and heart rate variability

In multiple regression (adjusted for age, marital status, BMI and smoking status), resilience was significantly associated with HF and LF/HF ratio during the work day and HF, LF and LF/HF ratio during the work evening (see Table 6.3). People with higher resilience scores had greater HF-HRV during the work day and evening periods, greater LF-HRV during the work evening and smaller LF/HF ratios during the work day and evening. Resilience remained a significant factor when adjusting for objective physical activity during the corresponding time period (model 2) and for total self-reported physical activity (model 3). Resilience was not related to any HRV measure during the leisure day and evening and was not related to heart rate during any time period.

6.3.3 Resilience and self-reported and objective physical activity

Resilience was significantly associated with all self-reported physical activity measures in regression, adjusting for age, marital status, BMI and smoking status (moderate exercise, $\beta = 0.297$, $SE = 0.072$, $p < 0.001$; vigorous exercise, $\beta = 0.234$, $SE = 0.074$, $p = 0.002$; total exercise, $\beta = 0.323$, $SE = 0.072$, $p < 0.001$). Resilient individuals reported more frequent exercise. However, resilience was not significantly related to objective physical activity during any time period.

Table 6.3: Regressions of resilience (as a predictor) on heart rate variability measures (DV)

		Time period							
		Work day				Work evening			
Heart rate variability (DV)	**Statistical model**	**β**	**SE**	**p**	**R^2**	**β**	**SE**	**p**	**R^2**
High Frequency (HF)	Regression 1	.184	.079	.022*	.078	.203	.071	.005*	.127
	Regression 2	.191	.078	.015*	.116	.212	.072	.004*	.131
	Regression 3	.192	.083	.021*	.129	.226	.077	.004*	.137
Low frequency (LF)	Regression 1	.043	.077	.577	.114	.182	.067	.008*	.222
	Regression 2	.051	.077	.511	.130	.180	.068	.009*	.222
	Regression 3	.020	.082	.806	.141	.177	.073	.016*	.222
LF/HF	Regression 1	-.164	.081	.045*	.046	-.152	.075	.046*	.025
	Regression 2	-.175	.080	.030*	.087	-.168	.076	.027*	.042
	Regression 3	-.223	.085	.009*	.098	-.198	.081	.015*	.047

$^*p \leq 0.05$, $^{**}p \leq 0.01$

Key: β = standardized regression coefficient for resilience as an independent variable, SE = standard error

Regression 1 = Adjusted for age, marital status, BMI and smoking status, Regression 2 = As regression 1, plus adjusted for objective physical activity during the corresponding time period, Regression 3 = As regression 2, plus adjusted for self-reported total physical activity

6.3.4 Self-reported physical activity and heart rate variability

A series of regression analyses tested associations between self-reported physical activity and the measures of heart rate and HRV across the different time periods in the study. Greater moderate and total exercise were associated with larger LF/HF ratios during the leisure evening only (moderate: β= 0.179, SE= 0.077, p= 0.022; total exercise:

β= 0.183, SE= 0.078, p= 0.021). There were no other significant relationships between self-reported physical activity and HRV measures (data not shown). There was also only limited correspondence between self-reported physical activity and objective activity measured using accelerometers. Participant's ratings of frequency of moderate, vigorous and total exercise predicted objective physical activity during the work evening after adjustment for age, marital status, BMI and smoking (moderate exercise, β= 0.256, SE= 0.072, p< 0.001; vigorous exercise, β= 0.228, SE= 0.072, p= 0.002; total exercise, β= 0.296, SE= 0.072, p< 0.001), but not at other time periods.

6.4 Discussion

We found that greater resilience was associated with higher HF and LF-HRV, and lower LF/HF ratio during the work evening and with higher HF-HRV and lower LF/HF ratio on the work day, independently of age, marital status, smoking, BMI, objective activity and self-reported physical activity. Higher resilience was also associated with a greater frequency of self-reported physical activity, but self-reported physical activity was not related to heart rate, HF or LF-HRV during any time period. Greater self-reported physical activity was related to greater LF/HF ratio during the leisure evening only. Greater objective activity was associated with higher heart rate for all time periods, lower HF and LF-HRV and higher LF/HF for the work day only.

The greater HF-HRV in participants with higher resilience scores during the work day and evening suggests a dominant influence of parasympathetic cardiac control. This pattern is associated with better cardiac health outcomes (Dekker, et al., 2000; Tsuji, et al., 1996). During the work evening, there was also an elevation in LF-HRV in more resilient individuals. The relationship between parasympathetic and sympathetic control of HRV is complicated, and HF and LF often increase or decrease in tandem (Thayer, et al., 2010). Although both components were higher in more resilient people during the work evening, the lower LF/HF ratio suggests that HF-HRV may be the more dominant component.

It is notable that the significant associations between HRV and resilience were independent of concurrent physical activity (model 2). Heart rate is higher when people are more active in order to sustain energy supplies to working muscle, and inverse associations between objective physical activity and HRV were observed during the work day. However, the association between resilience and greater HRV during the work day and evening remained significant after objective activity had been taken into account. Furthermore, resilience was not related to objective activity at any time point. These results indicate that the association between resilience and HRV was unlikely to be mediated by concurrent physical activity, implying that more direct autonomic mechanisms are probably responsible.

The results of this study may contribute to the understanding of resilience and HRV links since prior to the Daytracker study, the findings in this area were rather mixed and were limited to brief measures of HRV in very specific populations. The association between higher resilience and greater HF-HRV and reduced LF/HF ratio during the work period is in agreement with Souza et al (2013) who reported a positive relationship between ego-resilience and RMSSD (a measure of HRV thought to represent parasympathetic nervous activity). The current findings are also in the same direction as the non-significant positive associations between dispositional resilience and RMSSD HRV reported in Hallas et al (2003). Because we used 24 hour ambulatory heart rate measures adjusted for concurrent physical activity, taken in a naturalistic context and in a healthy sample, our results may be more applicable to resilience-health links within the general population (at least in women). The study design of Souza et al (2013) was focused on responses to acute laboratory stress tests in military men, which may not be comparable to ambulatory measures in an everyday setting as used in this study. Hallas et al (2003) examined relationships between resilience and HRV pre- and post-operation in a small sample of cardiac patients. Additionally, 40% of the participants were reported to have clinical levels of depression or anxiety pre-operation, which may have overshadowed any potential protective effects of resilience.

The current findings are compatible with the idea that people with higher resilience are better able to adapt to stress throughout the work day, which results in higher HF-HRV measures during the work day and evening (when any residual effects of stress experienced during the day may continue). These results are also complementary to studies showing lower HF-HRV and reduced time domain measures of HRV under stress (Chandola, et al., 2008; Hintsanen, et al., 2007). The greater levels of perceived stress during the work day and lack of association between resilience and HRV on the leisure day, adds further weight to the notion that resilience could be more relevant to periods of greater stress, or at least recovery from periods of stress. As resilience is implicated in adaptation to adversity, any potential protective effects are perhaps only seen during stressful periods. Alternatively, it could be that different psychosocial or physiological factors are of greater influence on HRV during the leisure day, such as social support or beneficial effects of rest and relaxation.

I hypothesized that regular physical activity may mediate between resilience and HRV, since participation in regular physical activity is associated with greater HRV. As anticipated, people with higher resilience reported a significantly greater frequency of taking moderate and vigorous exercise. This is in agreement with the findings of Resnick and Inguito (2011), Perna et al (2011) and Perez-Lopez et al (2014). As the study was cross-sectional, it is not possible to say whether taking regular physical activity improves resilience or that more resilient people are more likely to take frequent exercise. There is some evidence to suggest the relationship between emotional wellbeing and physical activity is bidirectional (Penedo & Dahn, 2005).

However, the notion that regular physical activity might mediate between resilience and HRV was not supported. There was no association between reported physical activity and HRV during the work periods, and no marked change in the regression coefficient of resilience on HRV when self-reported physical activity was added to the models (Table 6.3). The reason may be that the pathways linking resilience with HRV are independent of physical activity or physical fitness. This may also explain the lack of association between resilience and heart rate (which is closely linked to physical activity). Alternatively, limitations in the robustness of self-reported physical activity measures may be responsible (Shephard, 2003). It is notable that self-reported physical activity was not consistently related to objective measures in this study.

The results of this study are compatible with the possibility that resilience has a beneficial effect on cardiac health. There may be potential therapeutic value in resilience training to reduce the risk of heart disease either directly or indirectly. A pilot study suggested that measures of cardiac health such as total cholesterol levels could be reduced by resilience training (Burton, Pakenham, & Brown, 2010). It would be interesting to discover whether resilience training has favourable effects on HRV as well.

6.4.1 Limitations

We did not have an objective measure of physical fitness, but this would be interesting to include in future studies, as people who are physically fitter tend to have higher HRV (De Meersman, 1993). Additionally, interpretation of the LF/HF ratio remains controversial (Pomeranz, et al., 1985; Thayer, et al., 2010). One of the reasons for this controversy is the dispute over whether LF-HRV reflects only sympathetic influence or both sympathetic and parasympathetic (Eckberg, 1997). If the latter is true, as posited in this study, it may become difficult to assess the relative contributions of sympathetic and parasympathetic nervous influence, unless we know whether changes in the ratio are due to increases in HF or decreases in LF. Either way, the evidence presented in this study suggests a positive association between resilience and HF-HRV and an inverse association with LF/HF ratio during the work period, which may have implications towards cardiac health in the long term. Further general limitations of the Daytracker study are discussed in Chapter 7.

6.4.2 Conclusion

The study provides novel findings of an association between higher resilience and greater ambulatory HRV during a work day and evening in healthy women. Higher levels of self-reported physical activity did not explain this relationship, but were related to resilience. Further research may be able to ascertain whether resilience provides direct positive health benefits through modifications in autonomic function.

7 General discussion, limitations and implications of the resilience findings

7.1 Overview and discussion of the resilience findings

The three resilience studies add evidence for some of the links between resilience, stress, health behaviour and physiological and psychological factors that were outlined in the beginning of my thesis (Chapter 2, section 2.6). In Chapter 4, I found that resilience attenuates the association between stress exposure and affect and wellbeing outcomes, and that its impact was as a mediator rather than a moderator. These results may help to explain why resilient people enjoy better mental health: perhaps the risk of stress-induced distress and depression is reduced in people with higher resilience.

Chapters 5 and 6 provided modest evidence for links between resilience and health relevant biological factors, since resilience was associated with greater HRV but not reduced cortisol. I showed greater HF-HRV and lower LF/HF ratio in more resilient people during the work day suggesting greater parasympathetic and/or reduced sympathetic nervous activity. This pattern of cardiac activity is associated with better cardiac health, which suggests that resilience could be health protective in the context of cardiovascular disease. People with higher resilience also reported taking more frequent exercise which adds further support for the suggested link between resilience and health protective behaviours (see Chapter 2, section 2.6). However, self-reported physical activity was not consistently related to HRV. Therefore, the possibility that physical activity could be an indirect pathway between resilience and physiology was not confirmed in these analyses. In Chapter 5, I was not able to find any significant associations between cortisol and resilience, nor between daily stress and cortisol.

Considering that resilience is hypothesised to attenuate the impact of stress, it is clearly difficult to demonstrate relationships between resilience and cortisol when stress is not related to cortisol.

Some of the results across the three studies were consistent with previous findings in terms of the inverse relationship between resilience and self-reported stress, depression and negative affect, and positive relationships between resilience, positive affect and exercise frequency. However the lack of relationship between resilience and cortisol was not consistent with the idea that resilience may be health protective via this biological mechanism.

It could be that resilience as measured with the Resilience Scale is not relevant to stress processes that are related to the cortisol response. Or perhaps the relationship between resilience and cortisol is only apparent under more extreme conditions of stress. An alternative theory is that different kinds of stress have different biological 'signatures'. That is, there may be dissociation between the HPA axis and sympathetic-adrenal-medullary (SAM) responses for different categories of stress, as suggested by studies in both animals and humans (Pacák & Palkovits, 2001; Dayas, Buller, Crane, Xu, & Day, 2001; Schommer, Hellhammer, & Kirschbaum, 2003).

Resilience could be protective against the effects of certain kinds of stress and that the effects of these stressors are more apparent in measures of HRV. The previous chapters suggest that resilience may be more relevant to work stress, considering that resilience had a mediating influence between aspects of work stress and depressive symptoms and sleep problems (Chapter 4). Additionally, the association between resilience and HRV was only apparent during the work day (Chapter 6). Daily stress was greater on the work day compared with the leisure day so it could be that resilience is more relevant either to work stress specifically or to periods of greater stress in general.

Another consideration is that HRV is influenced by direct nervous influences whereas cortisol output is influenced by processes occurring during different stages of a series of chemical events in the HPA axis. The association between resilience and HRV was more apparent perhaps due to the more direct link between cognitive processes in the brain and the control of autonomic influences on the heart, compared to the indirect and more complicated system connecting cognition and cortisol output. Resilience could be indirectly related to cortisol via one of the numerous mediators of the HPA axis or there could simply be no relationship between resilience and cortisol.

Overall the results provide tentative evidence that there are links between resilience and some health relevant biological and psychological factors. This implies that people with higher resilience may be at reduced risk of illnesses such as depression and cardiovascular disease. Longitudinal studies assessing disease incidence will be needed to see whether this is the case. Additionally, experiments demonstrating causation (e.g. intervention studies) may help determine whether changes in resilience cause changes in biological correlates of health or whether they are co-occurring due to some other factor such as genetic linkage.

7.2 General limitations of the resilience studies

7.2.1 Participants

The Daytracker study was carried out with young healthy working women in London and Budapest, and this may not be the best group on which to test the impact of work stress. The demographic data for the London study sample showed a higher proportion of women with a degree or higher when compared to the national average: 63% in this study compared to approximately 19% of women in the UK in 2008 (Anyaegbu et al., 2010, Office for National Statistics). Also, the proportion of working mothers was 15% in this sample which was slightly lower than the estimated 20% in 2008 in London (Anyaegbu, et al., 2010, Office for National Statistics). The experience of work stress and other exposures in this group may be very different from that of older people with many years of work experience and other responsibilities.

However, the relatively homogeneous sample in the Daytracker study was also an advantage, because it allowed more precise estimations of the relationships between resilience and biological correlates such as cortisol (which is notoriously variable). Testing a sample of participants drawn randomly from the general public would have necessitated adjusting the analyses for additional variables such as gender and socioeconomic status. This may have limited the strength of the reported relationships unless a very large sample of participants was tested, which would have been impractical with the current design. Compared to other studies of daily affect and biology, the sample size in this study was already very substantial (around 200 women were recruited in both London and Budapest). The large sample size of the Daytracker study has allowed us to be more confident about the significance of the findings. Additionally, the study has allowed investigation into several areas of research that are currently under-represented by women (such as work stress and heart rate). This is particularly important considering that women are twice as susceptible to depression compared to men (Nolen-Hoeksema, 2001).

Despite the value of the Daytracker study in understanding the biological correlates of resilience in women, future replication of the study with men will be important. The majority of previous resilience studies have examined effects with women and there is some evidence to suggest that on average, men may be more resilient than women (Abiola & Udofia, 2011; Portzky, et al., 2010). However, it should be noted that other studies report no gender differences in resilience scores (Lundman, et al., 2007;

Nygren, et al., 2005). Additionally, there are thought to be sex differences in both cortisol regulation and HRV (Kudielka & Kirschbaum, 2005; Ryan, et al., 1994; Umetani, et al., 1998), so the resilience-biological marker relationships may also differ in men.

7.2.2 Design

The current study was cross-sectional, so no causal inferences can be drawn. A longitudinal design would be preferable for future studies, as this would allow for better estimates of the mediating influence of resilience. Changes to stress and biology could also be linked to possible changes in resilience in a longitudinal design. However, since resilience is often regarded as a relatively enduring personality trait, any differences when comparing cross-sectional to longitudinal results are likely to be modest.

There has been little research into natural changes in resilience over time using recognised resilience scales. There is only limited evidence of increases in resilience following interventions or treatment for psychological disorders. A longitudinal, naturalistic study of resilience would probably need to be conducted across the lifespan in order to detect any changes, especially as resilience is thought to increase with age (Lundman, et al., 2007; Portzky, et al., 2010).

Daily measurements were assessed over a single working and single leisure day. This sample of two days may not necessarily be representative of participants' usual experiences. However, there are very few studies of the same scope as the Daytracker study that utilise 2 monitoring days. The measurement of affect and biology over a work and a leisure day allowed contrasts to be made under different circumstances. As seen in Chapter 6, there were different relationships between resilience and HRV depending on the monitoring day. It may be that the associations seen here were sensitive to context –

a factor that may be missed in studies with one monitoring day or even several days taken across the working week but not the weekend.

7.2.3 Daily affect and stress measures

Although the Day Recollection Method (DRM) measures were daily reports, they were also retrospective since they were recalled over a 24-hour period including the previous evening. These measures may therefore be subject to a certain degree of recollection bias. The Ecological Momentary Assessment (EMA) measures may have been more accurate since they asked for assessments over the previous 30 minutes. They were, however, collected at the same time as the cortisol samples – a task that some participants (anecdotally) can find unpleasant and stressful. Also, the collection of the EMA measures was at pre-specified times (according to the cortisol samples) which were not evenly spread throughout the day. Therefore, the EMA measures of stress and affect may not have been truly representative of a typical day. However, it is difficult to get a true representation of a 'typical day' in *any* experiment, because being involved in a study alone makes the day atypical.

There is convincing evidence that EMA and DRM measures are reliable methods for measuring daily affect which have been well validated (e.g. Dockray, et al., 2010). Hence, the limitations listed above are minor. The inclusion of both DRM and EMA measures of daily affect and stress was useful because this allowed a choice of the most appropriate method to the individual analyses. For example, Chapter 5 included EMA measures of stress since these were more closely linked to the timing of the cortisol samples. Also, the ability to contrast daily measures of affect against questionnaire measures of affect was informative, as seen in Chapter 4. The role of resilience as a mediator was only apparent for questionnaire measures of affect but not daily measures, suggesting that the two measures may not necessarily be equated.

7.2.4 Issues of self-reported and objective measures

Chapter 4 examined associations between self-reported measures with no objective indicators. Corroboration of findings with more objective measures would be beneficial. For example, objective measures of neighbourhood deprivation could be compared with self-reported neighbourhood problems. It would be interesting to examine biases in self-report measures compared to resilience scores, where, for example more resilient individuals may under-report neighbourhood problems. Additionally, quantitative measures of sleep (such as duration and efficiency) from Actigraph recordings might be more insightful than self-reported sleep problems.

In Chapter 6, self-reported physical activity was not consistently related to the objective measures. Large disparities between self-report and objective measures of activity have been reported in population-based studies (e.g. Ham & Ainsworth, 2010). Objective measures of activity could be improved by asking the participants to wear activity monitors for longer periods e.g. one week, or level of fitness could be assessed in the laboratory.

In Chapter 5, discrepancies between self-reported and objective waking time may have influenced calculations of the CAR. A delay between waking and taking the 'waking' cortisol sample can result in a reduced CAR, since the CAR may have already begun. A study of the tolerance limits of this delay, suggests that up to 15 minutes is unlikely to affect the CAR. When the delay is greater than 15 minutes, waking cortisol concentration is greater compared to no delay or up to 15 minutes delay (Dockray, et al., 2008). This study also reported a mean discrepancy of around 6 minutes between self-reported and objective waking times (according to Actigraph activity monitors). However, a recent report on this matter suggests that even a delay of 5 to 15 minutes can affect the CAR estimate (Smyth, et al., 2013). Perhaps future studies could improve the CAR precision further by excluding participants with a delay of greater than 5 minutes between waking and taking the waking sample.

The procedure in this study was to adjust the self-reported wake times according to estimates from the Actiheart monitors if there was more than 10 minutes difference between the self-reported and objective time. Although having a more objective estimate of wake time is helpful in this respect, it also involves an element of subjective judgment. It is not possible to say for certain when someone has woken up or gone to sleep based on activity and heart rate alone, therefore this measure was only used as a guide in cases of discrepancy. Also, using the Actiheart data only allows for more objective estimates of waking but does not show the time the sample was actually taken (this was only indicated by the self-reported times in the saliva diary).

The Daytracker study therefore relied on self-reported estimates of delays between waking and taking the waking sample. Future studies could include saliva swab containers with internal time recording devices that become activated when the cap is opened (as used in Kudielka, Broderick, & Kirschbaum, 2003). This may help to improve the accuracy of the CAR (and diurnal cortisol measures), but would still need to be used in conjunction with an activity monitor to estimate wake times more objectively.

Additionally, the CAR calculations might have been improved by taking a greater number of samples in addition to the waking sample: for example at 15 minutes, 30 minutes and 45 minutes post-awakening (following the methods of Edwards, et al., 2001; Smyth, et al., 2013). Some studies have reported a stronger CAR with longer duration in women compared to men, so this may be particularly relevant for the Daytracker study (e.g. Kunz-Ebrecht, et al., 2004; Pruessner et al., 1997; Wüst, et al., 2000). However, it is noted that participants were already asked to collect 7 samples across each monitoring day so increasing this to 9 samples would have also increased the participant burden. Perhaps the number of samples collected during the rest of the day could have been reduced as a compromise.

Despite these limitations a major strength of the study is the inclusion of both subjective and objective measures, a factor lacking from many comparable studies. For example, the use of actigraphy to corroborate wake and sleep times was extremely useful and helped to improve the accuracy of the CAR calculations.

7.2.5 The Resilience Scale

The development and content of Wagnild and Young's (1993) Resilience Scale (RS) has been criticised for a number of reasons. One problem with the design of the scale is that it consists entirely of positive affirmations to which the participant is asked to agree or disagree. More stringent questionnaire designs usually include both positive and negatively worded statements, which may help to provide more consistent self-assessments and avoid response set bias.

Another consideration is the development of the scale from the original qualitative study. The 25-item scale was formulated from verbatim statements from 24 elderly women's accounts of how they had coped with a self-identified loss. As Windle et al (2011) point out, there is a lack of detail and clarity on how the themes were developed and the statements selected. Wagnild and Young (1993) provide a short literature review before introducing their scale, but there is a lack of transparency in how the individual items of the scale relate to the concepts set out in the literature. Despite this, the RS was given the highest rating for both content and construct validity according to the quality assessments in Windle and colleagues' review.

The RS may be most applicable to the population on which the scale was constructed (i.e. elderly women). The RS has been used in the wide range of populations, but accordingly has been used most commonly in women and particularly in the elderly. There may be other more suitable scales now available to measure resilience in the current study population. However, at the time the Daytracker study was devised, many of these scales were not extensively used and/or had not been validated to the same degree as the RS. Additionally, the only available review of resilience questionnaires at the time (Ahern, et al., 2006), suggested the RS as being the best measurement as of 2006. However, Ahern's review was limited in scope since it was based on assessing suitability of scales for use in adolescent populations. Also, this review did not employ a systematic approach to the assessment of the resilience scales available at the time.

The review by Windle and colleagues (2011) did utilize a systematic approach based on a stringent set of well-defined criteria. According to this review, the Resilience Scale for Adults (RSA), the Connor-Davidson Resilience Scale (CD-RISC) and the Brief Resilience Scale were rated most highly. The authors were not able to recommend any one of the 15 scales they reviewed as a 'gold standard' measure of resilience. Many scales lacked sufficient evidence for the assessment of important aspects of questionnaire design such as test-retest reliability and possible degree of floor or ceiling effects.

It is difficult to know whether the results may have been the same if a different scale to assess resilience had been used. In the absence of a 'gold standard' the most important concern is measuring resilience using a recognized scale rather than defining it as a lack of symptom development. Despite the issues with the Resilience Scale, it has been validated and well used so we were confident that it was a reliable indicator of resilience within the study sample.

7.2.6 Achievements of the Daytracker study

Overall, the Daytracker study was successful because it used a well-constructed design for exploring links between resilience and biological correlates of health. The main achievements are summarized as follows: 1) large samples of participants were recruited both in the UK and in Hungary from a relatively homogeneous population which allowed for the minimisation of potential confounding factors such as gender, 2) the findings of the studies have increased the knowledge base in several areas of research where women have been under-represented (e.g. heart rate and work stress), 3) a recognised and well regarded measurement of resilience was used, 4) affect was measured using both questionnaire and daily assessments, 5) a range of subjective and objective measures were used to assess a number of psychological, psychosocial and biological factors.

The design also allowed for the investigation of stress and biology in a naturalistic context which may be more applicable to resilience-health links compared with laboratory studies. There are very few studies investigating relationships between resilience and ambulatory HRV in an everyday setting. The majority of such studies in this area tend to be conducted in laboratory settings, typically following stress tests (e.g. Souza, et al., 2013; Souza, et al., 2007) and/or within patient samples (e.g. Hallas, et al., 2003).

The large number of cortisol samples collected across each monitoring day allowed the calculation of several different measures of cortisol regulation (total cortisol as area under curve, cortisol slope and CAR). Other studies investigating resilience and cortisol are scarce, and have used smaller numbers of both cortisol samples and participants when compared with the Daytracker study.

The assessment of biology across 2 different monitoring days allowed investigation of cortisol, HR and HRV differences in a work day compared to a leisure day, again in an area where evidence is minimal. In summary, despite the limitations, the studies of Chapters 4 to 6 make a substantial contribution to knowledge in a number of areas which are currently under-explored and poorly understood.

7.3 Implications of the resilience study results

The results of the resilience studies provide some support for the notion that higher resilience is associated with indicators of better mental and possibly physical health. Further research would help to validate the initial findings. However, the current findings indicate fruitful areas for future research in several applied settings as suggested below.

Resilience scores could be used to identify people who may be at higher risk for health problems following stress. People with low resilience could then be offered support. An application of this could be soldiers returning from combat scenarios following repeated exposures of high stress. Here, resilience scores could be used to help prioritise treatment strategies.

A second implication is that changes in resilience scores could be used to assess treatment success for psychological disorders such as depression or PTSD, as mentioned in Chapter 2 (section 2.4). As an example, psychiatrists could integrate regular resilience score measurement into treatment plans in order to gauge success.

Third, resilience training could be beneficial to health related outcomes. A specific example here might be integrating resilience interventions into long term chronic illness treatment in order to improve outcomes and save resources. It may be that resilience interventions need to be aimed at young adults or even children to have long lasting preventative effects in reducing susceptibility to mental and even physical health problems.

Existing resilience interventions tend to be intensive; typically lasting between 6 to 16 weeks and covering a wide variety of topics from coping skills to cultivating positive emotions (Fava & Tomba, 2009; Reivich & Shatte, 2003; Southwick & Charney, 2012). Resilience is multifaceted, so programmes aimed at improving resilience are necessarily complex and wide ranging.

As an example, the Penn Resiliency Program (one of the most well developed resilience interventions) is currently being used to help members of the US military in the 'Master Resilience Training' (MRT) course (Reivich, Seligman, & McBride, 2011). Skills taught on the MRT course include: cognitive reappraisal, identifying character strengths and using them to help overcome challenges, increasing optimism and cultivating gratitude. Some elements of the MRT course are based on techniques used in cognitive behavioural therapy (CBT) e.g. challenging negative thoughts, whereas other aspects are designed to encourage positive wellbeing and are based on concepts from positive psychology e.g. increasing optimism and cultivating gratitude.

So far, I have only investigated associations between resilience and specific correlates of health. If there is a causal link between resilience and health, then interventions to improve resilience may also be beneficial to health. Very few studies have provided robust evidence for changes in health-related measures following interventions designed to increase resilience. For example, Steinhardt et al (2009) reported changes in biological factors relevant to diabetes after a resilience intervention (described in Chapter 2, section 2.5). However, this was a pilot study of 12 participants.

In order to test possible causal routes between changes in positive wellbeing and changes in biological correlates of health, I was involved in a brief intervention study that is described in Chapter 9. In the context of my thesis, it would have been desirable to carry out an intervention designed specifically to enhance resilience, so as to assess the physiological consequences of such an effect. However, resilience interventions are complex and take a long time to administer, and there is currently very little convincing evidence to suggest resilience interventions with adults are likely to stimulate physiological changes. Given the lack of time and resources we had at our disposal, my colleagues and I decided to focus our expertise on implementing an intervention designed to increase positive wellbeing in general. Further information on the rationale for this study is detailed in the next chapter.

Although we did not conduct a resilience intervention, increasing positive wellbeing is still relevant to resilience. Some of the techniques used in resilience interventions such as expressing gratitude and encouraging greater optimism (as used in the MRT program described above) are aimed at increasing positive mood in general. Moreover, the importance of positive emotions in building and maintaining resilience was discussed in Chapter 2 (section 2.2) under Fredrickson's (2001) Broaden and Build theory. Positive emotions are thought to help broaden the range of cognitive processes and coping mechanisms necessary for dealing with stress and adversity, and to help build personal, social and other resources which contribute to resilience (Fredrickson, 2001, 2004).

8 Interventions to increase positive wellbeing

The evidence detailed in Chapter 1 suggests that biological variables such as heart rate and cortisol may be related to positive states and traits. However, the bulk of research has been cross-sectional, so causality has not yet been established. A potential explanatory mechanism for the positive wellbeing and health associations could be that there are differences in the biological correlates of health in people with a more positive outlook. It is possible that positive wellbeing improves biological function through cortico-limbic influences on peripheral regulatory systems. But biological function might also influence mood and central nervous system function (Dantzer, O'Connor, Freund, Johnson, & Kelley, 2008), so bidirectional processes may be involved. The most appropriate scientific method of assessing causal mechanisms is to carry out an experimental intervention. Interventions that are designed to increase positive wellbeing may be useful in determining whether changes to mental wellbeing are also associated with changes to health-related biological factors.

To determine which type of intervention would be most suitable for a planned study assessing changes in positive wellbeing and biology, the next section introduces a selection of tasks previously used to try to improve positive wellbeing. The most important consideration is whether the intervention could produce sufficient short-term improvement in wellbeing to make it plausible that impact on biological variables could be tested.

8.1 A review of selected positive wellbeing intervention studies

The intervention studies reviewed in this section derive from concepts in positive psychology. These intervention tasks were specifically designed to elicit increases in positive wellbeing using a variety of techniques from cultivating gratitude and optimism to writing about positive past experiences. This sets them apart from other interventions such as CBT or writing about traumatic experiences because although the outcome of the latter treatments can include increased positive wellbeing, they are not specifically designed to encourage positive feelings. To clarify the distinction, positive psychology based interventions (PPIs) can be defined as: "…treatment methods or intentional activities that aim to cultivate positive feelings, behaviors, or cognitions" (Sin & Lyubomirsky, 2009, p. 468).

The development of many PPI tasks was guided by research into the thoughts and behaviours exhibited by people who are naturally happy. For example, happy people tend to have an optimistic outlook on the future (Scheier & Carver, 1993) and show gratitude for the good things in life (McCullough, Emmons, & Tsang, 2002). These initial observations were then used to construct specific positive activities (e.g. keeping a gratitude journal) so that other people could boost their own positive wellbeing. The intentional practice of such positive activities is thought to improve mental wellbeing by increasing positive thoughts and emotions, reducing negative emotions and cognitions and encouraging positive outcomes in other areas of life such as increased social support (Layous, Chancellor, & Lyubomirsky, 2014). The initial increases in positive emotions and cognitions are thought to contribute to the 'upward spiral' of positive emotions and resources according to Fredrickson's (2001) Broaden and Build theory.

Convincing evidence that activities used in positive wellbeing interventions can indeed improve wellbeing comes from a meta-analysis of 51 studies (Sin & Lyubomirsky, 2009). This meta-analysis included 17 different types of interventions, ranging from brief self-administered written tasks to extensive 12 week programs of positive therapeutic techniques and life coaching. Collectively, these intervention tasks were found to be significantly better than comparison tasks or control groups for increasing positive wellbeing and reducing symptoms of depression, although effect sizes were wide ranging across the studies (r= -0.31 to 0.84). There were not enough studies of each type of intervention to see if any one task was consistently more effective. Sin and Lyubomirsky noted that in general, individual therapy was the most effective intervention format, followed by group administered interventions and then self-administered. Thus, a number of different positive wellbeing intervention tasks exist with differing effectiveness, although many have not yet been extensively developed or tested because they are still relatively new.

A selection of positive wellbeing intervention studies (mainly involving writing tasks) is presented in Table 8.1. The summary of results for each study is not necessarily exhaustive because I have only reported the differences in findings between intervention tasks and control or comparison tasks. For brevity, the results have been summarised to indicate the direction of significant findings i.e. whether changes in the experimental group following intervention were greater or less than the comparison group. Non-significant results have also been listed where relevant.

The methods and studies presented in this table were chosen based on relevance to the aim of selecting a suitable intervention task for the planned positive wellbeing intervention study, while taking into consideration the following constraining factors:

1. **Budget.** This was limited and allocated to processing biological samples and participant honorariums.
2. **Available personnel.** There was no access to specialists trained in techniques such as meditation or CBT. Therefore, the intervention had to be self-administered by the participants.

3. **Task difficulty.** The intervention had to be relatively simple and not too time consuming because we intended to recruit full time workers and graduate students as participants. Also we anticipated a fairly high participant burden due to the large number of biological and psychological measures.
4. **Task duration.** The task duration had to be longer than a single lab session (to allow adequate time for changes in wellbeing and biology to occur) but no more than a few weeks because we planned to have daily affect and sleep monitoring for a week before and after the intervention.

Thus, the intervention tasks selected for review were fairly simple, relatively short and self-administered. Other inclusion criteria for the studies in the table were as follows: i) the study included a measure of positive wellbeing assessed both before and after the intervention, ii) the study included a control or comparison task, iii) the significance of the results was established, iv) the participants were adults, and v) the participants were asked to perform a single intervention task rather than combinations of tasks. This last criterion was included as although multiple tasks can be effective, there are relatively few studies that have used the same combination of tasks, making assessments of their efficacy difficult.

It should be noted that papers which were not available at the time the study was devised, have been included in Table 8.1 (indicated with an asterisk) and that the list of interventions presented in this section is not exhaustive. A short review of meditation-based interventions is provided in section 8.2. Although we did not have the resources for a meditation intervention, it remains one of the only tasks to look at changes in biology alongside positive wellbeing.

8.1.1 Gratitude interventions

In 2003, Emmons and McCullough devised a gratitude-based intervention, also known as ‘counting one’s blessings’, where participants were asked to list 5 things for which they were grateful (see Table 8.1 for results of their seminal study). Gratitude could be expressed for things both large and small, including thankfulness to people, for material items and for the wider world in general e.g. gratitude for nature or for life itself. The theoretical basis for the task was developed following studies suggesting associations between trait and state gratitude and positive wellbeing (Emmons & Shelton, 2002; McCullough, et al., 2002).

A variation to the original method has also been devised whereby participants are asked to write a ‘gratitude letter’ expressing thanks to a person who has been helpful in some way (Lyubomirsky, Dickerhoof, Boehm, & Sheldon, 2011; Seligman, Steen, Park, & Peterson, 2005). According to different methodologies, this gratitude letter can then either be read aloud or sent to the letter recipient, or (more commonly) the participants can keep the letter to do whatever they wish with it.

Several studies using gratitude lists (in Table 8.1) reported improvements in positive wellbeing in participants assigned to the gratitude task relative to control or comparison tasks. These included increases in positive affect (Emmons & McCullough, 2003; Martinez-Marti, Avia, & Hernandez-Lloreda, 2010), happiness (Sergeant & Mongrain, 2011; Toepfer, Cichy, & Peters, 2012), life satisfaction (Boehm, Lyubomirsky, & Sheldon, 2011a; Emmons & McCullough, 2003; Toepfer, et al., 2012), and composite measures of wellbeing (Lyubomirsky, et al., 2005a).

Table 8.1: Summary of positive wellbeing intervention studies

Authors	**Duration/ frequency**	**Participants**	**Intervention task (N)**	**Comparison/ control task (N)**	**Results for intervention task versus (vs) comparison or control task**
Interventions based on gratitude lists					
Emmons & McCullough (2003) *Study 1*	10 weeks/ weekly	Under-graduate psychology students	*Gratitude lists (N= 65)*	Listing hassles (N= 64)	*Pre- to post-intervention, Gratitude > hassles*: gratitude, life satisfaction (general & expected in the next week) & hours spent exercising. *Gratitude < hassles*: physical symptoms (self-reported). *Not significant*: positive & negative affect
				Control: listing events that 'had an impact' (N= 67)	*Gratitude > events list*: life satisfaction (general & expected in the next week). Gratitude < events list: physical symptoms. *Not significant*: positive & negative affect, gratitude, hours spent exercising
Study 2	2 weeks/ daily	Under-graduate psychology students	*Gratitude lists (N= 52)*	Listing hassles (N= 49)	*Pre- to post-intervention, Gratitude > hassles*: positive affect, gratitude, offering social support to others. *Not significant*: negative affect, physical health, hours spent exercising, health behaviours, helping someone with a problem & frequency of helping others
				Downward social comparison (N= 56)	*Gratitude > social comparison*: offering social support to others. *Not significant*: positive & negative affect, gratitude, physical health, hours spent exercising, health behaviours, helping someone with a problem & frequency of helping others
Study 3	3 weeks/ daily	Patients with neuro-muscular disease	*Gratitude lists (N= 33)*	No treatment (N= 32)	*Pre- to post-intervention, Gratitude > no treatment*: positive affect (both self-rated & as rated by a significant other), gratitude, connection with others, general life satisfaction & expected life satisfaction, time spent sleeping & feeling refreshed on waking. *Gratitude < no treatment*: negative affect. *Not significant*: pain, pain interfering with daily life, negative affect as rated by significant other, time spent exercising & functional status

Authors	Duration/ frequency	Participants	Intervention task (N)	Comparison/ control task (N)	Results for intervention task versus (vs) comparison or control task
Gratitude lists (continued)					
Lyubomirsky, Sheldon & Schkade (2005b)†	6 weeks/ once or 3 times per week	College students (N not reported)	*Gratitude lists (contemplated, not written)*	No treatment	*Pre- to post-intervention, Gratitude once a week > no treatment*: wellbeing composite measure. *Not significant*: gratitude 3 times a week vs no treatment for wellbeing composite measure
Sheldon & Lyubomirsky (2006)	2 weeks/ at least twice over 2 weeks	Under-graduate psychology students	*Gratitude lists (N=21)*	Best possible self (BPS) (N= 23) Control: thinking about the day (N= 23)	*Pre- to post-intervention, gratitude vs BPS*: no significant differences in positive or negative affect *Gratitude vs control*: no significant differences in positive or negative affect
Martinez-Marti et al (2010)	2 weeks/ daily	Under-graduate psychology students	*Gratitude lists (N= 41)*	Listing hassles (N= 30) Control: listing events that affected you (N= 34)	*Pre- to post-intervention, Gratitude > hassles*: positive affect, state gratitude. *Not significant:* negative affect, subjective wellbeing, physical symptoms, use of pain relievers, sleep quality, relationship quality, sensitivity to other's needs, trait gratitude. *2 week post-intervention follow up*: no significant differences between gratitude & hassles for any of the variables. *Pre- to post-intervention & at 2 week post-intervention follow up*: No significant differences between gratitude & control for any of the variables.

†a preliminary study included as part of a review paper with limited methodological details (included in this table as it has a useful comparison of task frequency)

Note: The table is continued on the next page

Authors	**Duration/ frequency**	**Participants**	**Intervention task (N)**	**Comparison/ control task (N)**	**Results for intervention task versus (vs) comparison or control task**
Gratitude lists (continued)					
Sergeant & Mongrain (2011)*	1 week/ daily	Members of the public (online)	*Gratitude lists (Total N = 772, N by condition not reported)*	Control: writing about early memories	*Across 5 time points (baseline, post-intervention, 1 month, 3 months & 6 months follow up), Gratitude > control*: happiness. *Not significant*: depression, self-esteem, physical symptoms.
Peters et al (2013)*	1 week/ 3times	Mainly university students	*Gratitude lists (N= 26)*	BPS (N= 28) Control: writing about everyday events (N= 28)	*Pre- to post-intervention & at 1 week post-intervention, Gratitude vs BPS:* No significant differences in life satisfaction or optimism, although both measures increased over time in the gratitude condition *Pre- to post-intervention & at 1 week post-intervention, Gratitude vs control:* No significant differences in life satisfaction or optimism

Key: BPS = Best possible self, * Papers not available at time of project conception, but have been included in this table for review purposes

Note: The table is continued on the next page

Authors	**Duration/ frequency**	**Participants**	**Intervention task (N)**	**Comparison/ control task (N)**	**Results for intervention task versus (vs) comparison or control task**
Interventions involving letters of gratitude					
Seligman et al (2005)	1 week to write & deliver gratitude letter	Members of the public (online)	*Gratitude letter (N=80)*	Control: writing about early memories (N= 70)	*At post-intervention, 1 week & 1 month follow up, Gratitude > control*: happiness. *Gratitude < control*: depressive symptoms. No significant differences at 3 months & 6 months follow up
Lyubomirsky et al (2011)*	8 weeks/ weekly	Under-graduate students (online)	*Gratitude letter (N=108)*	Control: events over the last week (N= 110)	*From baseline to post-intervention & from baseline to 6 months follow up*: no significant differences between gratitude & control for wellbeing composite measure. *For self-selected participants (those who knew the study was about increasing wellbeing), gratitude > control* for wellbeing composite measure. Effort was a significant predictor of wellbeing in the gratitude condition but not the control
Boehm et al (2011a) *	6 weeks/ weekly for 10 minutes	Members of the public (online)	*Gratitude letter (N= 72)*	Control: events over the last week (N= 74)	*Across 3 time points from baseline to post-intervention to 1 month follow up, Gratitude > control:* life satisfaction. Anglo-Americans benefitted more from the gratitude task compared with Asian Americans (in terms of increased life satisfaction)
Toepfer et al (2012) *	3 weeks/ weekly	University research pool	*Gratitude letter (N= 105)*	No treatment (N= 78)	*Pre- to post-intervention, Gratitude > no treatment*: happiness, life satisfaction. *Gratitude < no treatment*: depressive symptoms. *Not significant*: gratitude
Proyer et al (2014)*	1 week/ once for gratitude letter, daily for control	Older women (aged 50-79 years old)	*Gratitude letter (N=30)*	Control: early memories (N= 34)	*At 1 month post-intervention, Gratitude >control:* happiness. *Gratitude < control*: depressive symptoms. *Not significant*: happiness & depressive symptoms pre- to post-intervention & at 3 and 6 months follow up.

* Papers not available at time of project conception, but have been included in this table for review purposes

Authors	**Duration/ frequency**	**Participants**	**Intervention task (N)**	**Comparison/ control task (N)**	**Results for intervention task versus (vs) comparison or control task**
'Best possible self'(BPS) interventions					
King (2001)	4 days/ daily for 20 minutes	Under-graduate students	*BPS (N= 19)*	Writing about a trauma (N= 22) Control: writing about plans for the day (N= 16)	*Pre- to post-intervention, BPS > trauma*: net positive affect (positive minus negative affect) *One semester prior to intervention compared with 5 months after intervention, BPS < control*: visits to the doctor (objective measure from medical records). *Pre- to post-intervention, not significant*: net positive affect
Sheldon & Lyubomirsky (2006)	2 weeks/ at least twice over 2 weeks	Under-graduate psychology students	*BPS (N= 23)*	Gratitude lists (N= 21) Control: thinking about the day (N= 23)	*Pre- to post-intervention, BPS vs gratitude*: no significant differences in positive or negative affect *BPS > control*: positive affect. *Not significant*: negative affect
Lyubomirsky et al (2011)*	8 weeks/ weekly	Under-graduate students (online)	BPS *(N= 112)*	Control: events over the last week (N= 110)	*From baseline to post-intervention & from baseline to 6 months follow up*: no significant differences between BPS & control for wellbeing composite measure. *For self-selected participants (those who knew the study was about increasing wellbeing), BPS > control* for wellbeing composite measure. Effort was a significant predictor of wellbeing in the BPS condition but not the control
Boehm et al (2011a) *	6 weeks/ weekly for 10 minutes	Members of the public (online)	*BPS (N= 74)*	Control: events over the last week (N= 74)	*Across 3 time points from baseline to post-intervention to 1 month follow up, BPS > control:* life satisfaction. Anglo-Americans benefitted more from the BPS task compared with Asian Americans (in terms of increased life satisfaction)

Key: BPS = Best possible self, * Papers not available at time of project conception, but have been included in this table for review purposes

Authors	Duration/ frequency	Participants	Intervention task (N)	Comparison/ control task (N)	Results for intervention task versus (vs) comparison or control task
'Best possible self' (BPS) interventions (continued)					
Seear & Vella-Brodrick (2012)*	1 week/ daily	Members of the public	*BPS (N= 21)*	No treatment (N= 29)	*Pre- to post-intervention, BPS < no treatment*: negative affect. *Not significant*: negative affect at 2 week follow up, positive affect & mental wellbeing at all time points
Layous et al (2013b) *	4 weeks/ weekly	Under-graduate psychology students	*BPS (N= 81)*	Control: activities over the past 24 hours (N = 38)	*Pre- to post-intervention, BPS > control*: positive affect, flow. *Not significant*: relatedness, autonomy, competence, need satisfaction
Peters et al (2013)*	1 week/ 3times	Mainly university students	*BPS (N= 28)*	Gratitude lists (N= 26) Control: writing about everyday events (N= 28)	*Pre- to post-intervention & at 1 week post-intervention, BPS vs Gratitude:* No significant differences in life satisfaction or optimism, although both measures increased over time in the BPS condition *Pre- to post-intervention, BPS > control:* life satisfaction. *Not significant*: life satisfaction at 1 week post-intervention, optimism at any time point

Key: BPS = Best possible self, * Papers not available at time of project conception, but have been included in this table for review purposes

Note: The table is continued on the next page

Authors	Duration/ frequency	Participants	Intervention task (N)	Comparison/ control task (N)	Results for intervention task versus (vs) comparison or control task
Writing about positive past experiences (PPE)					
Burton & King (2004)	3 days/ daily for 20 minutes	Under-graduate psychology students	*PPE (N= 48)*	Control: writing about day plans, your bedroom & shoes (N= 42)	*At post-intervention, PPE > control*: positive affect. *PPE < control*: health centre visits due to illness. *Not significant*: negative affect
Wing et al (2006)	3 days/ daily for 20 minutes	Under-graduate psychology students & members of the public	*PPE (N= 62)* *PPE plus cued emotional regulation (N= 58)*	Control: writing about plans for the day (N= 55)	*Pre- to post-intervention, PPE > control & PPE plus cue > control*: emotional intelligence. *Not significant*: life satisfaction, emotional intelligence at 2 weeks follow up *PPE only vs PPE plus cue, Not significant*: life satisfaction and emotional intelligence at any time point
Burton & King (2008)	2 days/ daily for 2 minutes	Under-graduate psychology students	*PPE (Total N= 49, N by condition not reported)*	Writing about a traumatic experience Control: writing about the campus & your shoes	*At post-intervention, PPE > trauma:* positive affect. *Not significant:* physical symptoms (self-reported) 4-6 weeks after the intervention, negative affect *PPE < control:* self-reported illness 4-6 weeks after the intervention. *Not significant:* positive affect, negative affect
Burton & King (2009)	3 days/ daily for 20 minutes	Under-graduate psychology students	*PPE (N= 19)*	Control: writing about the college campus, your bedroom & shoes *(N= 19)*	*Pre-intervention to post-intervention (ratings after each writing task averaged across 3 days), PPE > control*: positive affect. *PPE < control:* negative affect, physical symptoms (self-reported) 4-6 weeks after the intervention

Key: PPE = positive past experiences

Authors	Duration/ frequency	Participants	Intervention task (N)	Comparison/ control task (N)	Results for intervention task versus (vs) comparison or control task
Acts of kindness (kind acts)					
Lyubomirsky, Sheldon & Schkade (2005b) †	6 weeks/ 5 acts in 1 day or across each week	College students (N not reported)	*Kind acts*	No treatment	*Pre- to post-intervention, Kind acts one day per week > no treatment*: wellbeing composite measure. *Not significant*: kind acts spread across the week vs no treatment for wellbeing composite measure
Otake et al (2006), study 2	1 week/ daily	Female under-graduate psychology students	*Listing spontaneous kind acts (N= 71)*	No treatment (N= 48)	*Pre- to post-intervention & at one month follow up, Kind acts > no treatment:* happiness
Alden & Trew (2013)*	4 weeks/ 3 acts on 2 days each week	Students with high social anxiety	*Kind acts (N= 43)*	Control: recording daily events (N= 43)	*Pre- to post-intervention, Kind acts > control*: positive affect, relationship satisfaction. *Kind acts < control*: social avoidance. *Not significant*: negative affect, social approach.

†a preliminary study included as part of a review paper with limited methodological details (included in this table as it has a useful comparison of task frequency)**,** * Papers not available at time of project conception, but have been included in this table for review purposes

Note: The table is continued on the next page

Authors	Duration/ frequency	Participants	Intervention task (N)	Comparison/ control task (N)	Results for intervention task versus (vs) comparison or control task
Interventions based on personality strengths					
Seligman et al (2005)	1 week/ daily	Members of the public (online)	*Strengths (N= 66)* *Identifying (but not using) strengths (N = 68)*	Control: writing about early memories (N= 70)	*At 1 week, 1 month, 3 months & 6 months follow up Strengths > control*: happiness (no significant difference at post-intervention). *Strengths < control*: depressive symptoms at all time points *At post-intervention, Identifying strengths > control*: happiness. *Identifying strengths < control*: depressive symptoms. *Not significant*: happiness & depression at all other time points (i.e. the follow up times as listed above)
Mitchell et al (2009)	3 weeks/ weekly sessions with tasks in between	Members of the public (online)	*Strengths (N= 17)*	Control: reading about problem solving but not applying it (N= 23)	*From baseline to post-intervention & 3 month follow up, Strengths > control*: life satisfaction (Personal Wellbeing Index), pleasure subscale from the Orientations to Happiness (OTH) scale. *Not significant*: positive affect, negative affect, life satisfaction (Satisfaction with Life Scale), mental health and the engagement and meaning subscales of the OTH scale
Mongrain & Anselmo-Matthews (2012)*	1 week/ daily	Members of the public (online)	*Strengths (N= 74)*	Control: early memories (N= 81) Positive placebo: positive early memories (N= 87)	*Pre- to post-intervention, at 1 month and 6 months follow up, but not 3 months, Strengths > control*: happiness. *Not significant*: depression *No significant differences* in happiness and depression for strengths vs positive placebo. N.B. Happiness increased in both the positive placebo group and the strengths group
Proyer et al (2014)*	1 week/ daily	Older women (aged 50-79 years old)	*Strengths (N= 35)*	Control: early memories (N= 34)	*Pre- to post-intervention & at 1, 3 and 6 months follow up Strengths >control:* happiness *Pre- to post-intervention & at 1 month, but not 3 and 6 months follow up Strengths < control:* depression.

* Papers not available at time of project conception, but have been included in this table for review purposes

Authors	**Duration/ frequency**	**Participants**	**Intervention task (N)**	**Comparison/ control task (N)**	**Results for intervention task versus (vs) comparison or control task**
'Three good things' interventions					
Seligman et al (2005)	1 week/ daily	Members of the public (online)	*3 good things (N= 59)*	Control: writing about early memories (N= 70)	*At 1 month, 3 months & 6 months follow up 3 good things > control*: happiness (non-significant at post-intervention & at 1 week follow up). *3 good things < control*: depressive symptoms at all time points
Seear & Vella-Brodrick (2012)*	1 week/ daily	Members of the public	*3 good things (N= 26)*	No treatment (N= 29)	*Pre- to post-intervention & at 2 weeks follow up:* no significant differences for positive affect, negative affect & mental wellbeing
Mongrain & Anselmo-Matthews (2012)*	1 week/ daily	Members of the public (online)	*3 good things (N= 102)*	Control: early memories (N= 81) Positive placebo: positive early memories (N= 87)	*Pre- to post-intervention, at 3 months and 6 months follow up, but not 1 month, 3 good things > control*: happiness. *Not significant*: depression *No significant differences* in happiness and depression for 3 good things vs positive placebo. N.B. Happiness increased in both the positive placebo group and the 3 good things group
Proyer et al (2014)*	1 week/ daily	Older women (aged 50-79 years old)	*3 good things (N= 44)*	Control: early memories (N= 34)	*Pre- to post-intervention 3 good things > control*: happiness, *3 good things < control*: depressive symptoms (non-significant for both measures at 1, 3 & 6 months follow up).

* Papers not available at time of project conception, but have been included in this table for review purposes

It seems that the duration and frequency of the gratitude list task may influence the findings for positive wellbeing. For example, Emmons and McCullough (2003) found that positive affect increased in students assigned to the gratitude group when the task was performed daily for 2 weeks (study 2), but not when gratitude lists were completed weekly for 10 weeks (study 1). Lyubomirsky et al (2005a) found increases in wellbeing when students expressed gratitude once per week, but not 3 times per week, across 6 weeks. Thus, the gratitude list task appears to be more effective for shorter durations and with lower frequency for 6 week interventions.

Additionally, there were differences in findings according to the comparison task. Emmons and McCullough (2003) reported significant increases in positive affect when comparing the gratitude list task with writing about daily hassles (study 1). However, changes in positive affect were no longer significant when the gratitude condition was compared with listing ‘events that had an impact’ (study 1) and with a downward social comparison task (study 2). Similar results were found in a replication of study 1 by Martinez-Marti, Avia and Hernandez-Lloreda (2010). Relative to the Best Possible Self task (described in section 8.1.2.1) and a control task of ‘thinking about the day’, Sheldon and Lyubomirsky (2006) found no significant effects of keeping gratitude lists on both positive and negative affect. However, the participant numbers in this latter study were rather small and the task was performed infrequently (at least 2 times over 2 weeks).

Surprisingly, increases in gratitude (in the gratitude condition) were not consistently found. Significant changes were only seen when the gratitude condition was compared with the hassles condition in Emmons and McCullough (2003, studies 1 and 2) and Martinez-Marti et al (2010). Indeed, the mechanisms driving improvements in wellbeing following gratitude interventions are still not fully understood and are not necessarily due to changes in gratitude (Wood, Froh, & Geraghty, 2010).

The results of studies including measures of self-reported health and health behaviours tend to be mixed. For example, Emmons and McCullough (2003) reported reduced physical symptoms in participants completing gratitude lists for 10 weeks (study 1) and increased time spent sleeping and feeling refreshed on waking in patients with neuromuscular disease (study 3). However, other measures of self-reported health or health behaviours did not change e.g. hours spent exercising, functional status, sleep quality, pain and use of pain relief (Emmons & McCullough, 2003, studies 2 and 3; Martinez-Marti, et al., 2010; Sergeant & Mongrain, 2011). It could be that changes in physical health only become apparent in longer interventions, or those involving patient groups.

Despite several studies finding increases in positive wellbeing following gratitude tasks, there was very little evidence for reduced negative affect and depression. The majority of studies report non-significant results for negative affect e.g. Emmons and McCullough (2003); studies 1 and 2 (but not study 3), Sheldon and Lyubomirsky (2006) and Martinez-Marti et al (2010). Significant decreases in depressive symptoms were found in studies using gratitude letters (Proyer, et al., 2014; Seligman, et al., 2005; Toepfer, et al., 2012), but not with gratitude lists (Sergeant & Mongrain, 2011). However, the latter study was the only gratitude list study to measure depression.

The results for measures of positive wellbeing in gratitude letter studies were similar to the gratitude list studies. Increases in happiness and life satisfaction were found in participants assigned to the gratitude letter task relative to control tasks or no treatment (Boehm, et al., 2011a; Proyer, et al., 2014; Seligman, et al., 2005; Toepfer, et al., 2012). However, it seems that the gratitude lists task has been more extensively tested.

8.1.2 Positive writing tasks

The act of writing about experiences has long been used as a therapeutic technique. Most notably, one can refer to the methods of disclosive writing developed by Pennebaker as a therapy for traumatic experience (e.g. Pennebaker, 1997). Recently, several methods of positive writing have been developed where participants are specifically guided to focus on positive events, rather than writing about emotionally upsetting experiences. Two of the more popular positive writing tasks include writing about the future in the ‘Best possible self’ (BPS) task and writing about positive past experiences.

8.1.2.1 The ‘Best possible self’ (BPS) task

The BPS task (King, 2001) was developed as an alternative writing task to avoid the emotional upset associated with writing about traumatic experiences. It is often described as an optimism intervention, because it involves imagining yourself in the future at your best and describing the characteristics and circumstances of your best possible self, for example in terms of future relationships, work and family life. King’s initial results suggested that participants assigned to the BPS task showed significant increases in net positive affect only when compared with the traumatic experiences group but not compared with the control group (as seen in Table 8.1). However, the BPS group had fewer visits to the doctor due to illness (assessed via medical records) in the 5 month period after the intervention, when compared with the control group. These results were found after only 4 days of writing about BPS daily.

Other BPS intervention studies have found beneficial effects (compared with controls), for positive affect (Layous, et al., 2013b; Sheldon & Lyubomirsky, 2006), flow (Layous, et al., 2013b), life satisfaction (Boehm, et al., 2011a; Peters, et al., 2013) and a wellbeing composite measure in self-selected participants only (Lyubomirsky, et al., 2011). However, there were reports of non-significant differences in positive wellbeing e.g. Seear and Vella-Brodrick (2012) and in Lyubomirsky et al (2011) for non self-selected study participants. (In this latter study, ‘non self-selected’ refers to participants who were blind to the study aim of increasing wellbeing at recruitment).

Results for negative affect and mental health were also rather mixed. Seear and Vella-Brodrick (2012) reported significant decreases in negative affect immediately after the intervention, but not at 2 weeks follow up. They found no difference in mental wellbeing. Sheldon and Lyubomirsky (2006) also found no significant differences in negative affect following the BPS task, when compared with gratitude lists and a control task.

8.1.2.2 Positive past experiences

Recalling and writing about positive past experiences (PPE) was initially developed by Burton and King (2004), again as an alternative to writing about traumatic experiences. In this task, participants were asked to recall and write in detail about a time or event in the past when they had a positive experience. Burton and King (2004, 2009) found significant increases in positive affect and fewer health centre visits for participants completing the PPE task compared with a neutral control task. However, when the task was shortened to just 2 minutes per day for 2 days, increases in positive affect in the PPE condition were only significant when compared with writing about traumatic experiences (Burton & King, 2008).

Wing, Schutte and Byrne (2006), repeated the method of Burton and King (2004), with an additional variation of the task involving an emotional regulation cue. This cue was to consider and write about how to increase the frequency of ‘tapping into’ or repeating the positive feelings induced by the positive writing exercise. However, this additional cue did not improve the efficacy of the original intervention in increasing life satisfaction or emotional intelligence; the results were very similar for the “PPE only” and the “PPE plus cue” conditions (as seen in Table 8.1).

Negative affect did not change following PPE tasks on the whole, e.g. Burton and King (2004, 2008), with the exception of Burton and King (2009) where negative affect decreased. Finally, there was some evidence that PPE tasks improved self-reported physical health (Burton & King, 2008, 2009).

8.1.3 Acts of kindness

Interventions based on encouraging participants to commit acts of kindness towards others e.g. cooking for a housemate, giving somebody help with a chore, have found a few promising results. For example, Alden and Trew (2013), reported increases in positive affect and relationship satisfaction in students with high levels of social anxiety, after performing kind acts (see Table 8.1). In a slight variation by Otake et al (2006), where participants listed spontaneous acts of kindness rather than being instructed to carry out kind acts, participants reported increases in happiness from pre- to post-intervention and at a one month follow up. Lyubomirsky et al (2005a) suggest that performing 5 kind acts on one day each week for 6 weeks is more effective in increasing wellbeing, than the same number of kind acts spread across the week.

Performing acts of kindness is thought to be effective because it involves pro-social behaviour, which may contribute to positive wellbeing via Fredrickson’s (2004) ‘Broaden and Build’ idea of increasing personal resources (such as strengthening social relationships), and may encourage reciprocity (Layous, Nelson, Oberle, Schonert-Reichl,

& Lyubomirsky, 2012). However, there seem to be very few studies using acts of kindness to increase positive wellbeing.

8.1.4 Personality strengths-based interventions

A character strengths-based intervention was devised by Seligman et al (2005), based on positive personality characteristics identified by the VIA (Values In Action) survey of character strengths (see www.authentichappiness.com). Following the survey, participants are given feedback on their top 5 ‘signature’ strengths (Peterson, Park, & Seligman, 2005), and instructed to use one signature strength in a ‘new and different way’ every day for 7 days. Seligman et al (2005) also devised a variation of this task whereby participants were instructed to use their signature strengths ‘more often’ during the week but not specifically instructed to use their strengths in new ways every day. The results of this study suggested that participants in the original strengths task had increased happiness (compared with baseline) at all follow up time points (1 week, 3 months and 6 months), but not immediately post-intervention, and reduced depression at all time points. However, participants assigned to identifying strengths only (without the enhanced instructions of the original task) showed increased happiness and decreased depression immediately post-intervention but at no other time point.

The results of a couple of replication studies using the original strengths task were fairly similar. Happiness was greater in the strengths group versus control at all time points except 3 months follow up (Mongrain & Anselmo-Matthews, 2012; Proyer, et al., 2014). The latter replication also extended the study by comparing the strengths task with a positive placebo task (writing about positive early experiences). Happiness increased in both the strengths group and the positive placebo, but there were no significant differences between the 2 conditions, suggesting that the strengths task was no better than a positive writing task.

A more structured, online version of the strengths task was devised by Mitchell and colleagues (2009). In this study, participants were asked to complete weekly sessions online to identify and use signature strengths and were asked to complete offline tasks such as talking to a friend about what they had learned. Despite initially recruiting 160 participants to the study, there was a very high attrition rate (70% at post-intervention and 83% at follow up), which the authors attributed to the online delivery. The results for Mitchell et al (2009) were fairly mixed, with significant increases in pleasure and one measure of life satisfaction, but no difference in positive and negative affect, mental health and a second measure of life satisfaction, when compared with a control task (reading about problem solving).

8.1.5 'Three good things' task

Another relatively simple intervention described in the Seligman et al (2005) study, involved writing about 3 good things that happened each day and the causes behind them. The theoretical background for this task was not explicitly stated, but it is relevant to the concept that savouring positive experiences improves mood (Jose, Lim, & Bryant, 2012). In the original study, significant increases in happiness were only seen at longer follow up time points, rather than immediately at post-intervention (Seligman, et al., 2005). However, in Mongrain and Anselmo-Matthews's (2012) replication, there was increased happiness (compared with baseline) in the 3 good things group at all time points, except at 1 month follow up.

A comparison of the 3 good things task and a positive placebo suggested that 3 good things was not any more beneficial than a general positive writing task; although happiness increased in the 3 good things condition, it also increased to a similar extent when writing about positive early memories (Mongrain & Anselmo-Matthews, 2012). Depressive symptoms were found to be less than baseline at all time points in Seligman et al (2005), but Mongrain and Anselmo-Matthews (2012) reported no significant results here. Seear and Vella-Brodrick (2012) did not find any significant results (for positive and negative affect and mental wellbeing), however they did have the smallest number of participants out of all the 3 good things studies reported here.

8.2 Meditation-based interventions

Meditation based interventions appear to be the most extensively tested for changes in biology. Such interventions have been found to: i) improve positive wellbeing through increased quality of life, positive mood states and self-esteem, ii) reduce negative mood states, anger, symptoms of anxiety and depression, and iii) improve self-reported physical health in patients as seen by a reduced number of medical symptoms reported, increased physical functioning and pain tolerance (Schneider & Huppert, 2009). Effect sizes for improvements in psychological factors are suggested to be similar to those reported in trials of behavioural interventions and psychotherapy (Sedlmeier et al., 2012).

A qualitative review of various meditation interventions (Goldstein, Josephson, Xie, & Hughes, 2012) suggested that meditation could be used to induce small (but clinically significant) reductions in blood pressure. There is also some evidence that meditation-based interventions have an effect on immune and neuroendocrine function in non-patient samples. For example, increased antibody production following influenza vaccine, reduced inflammation and steeper cortisol slopes were found following meditation interventions (Davidson et al., 2003; Rosenkranz et al., 2013). Participants in a 5 day, brief, intensive meditation training course also showed reduced cortisol after 5 minutes of a stressful task followed by 20 minutes of meditation (Tang et al., 2007). These findings are useful as they will help guide expected outcomes for the biological variables in the planned intervention study.

8.3 Comparison of the positive wellbeing intervention methods

In order to select the best task for the planned study, the practicable interventions (listed in section 8.1) were compared for their relative merits and efficacy in inducing increases in positive wellbeing. It was important to select a method that reliably increased measures of positive wellbeing, so that causal inferences could be made of the effects on biological correlates of health. Unfortunately, as discussed in the review, the results of each type of intervention were fairly mixed; there was not one single intervention that produced consistent increases in positive wellbeing.

Based on the literature available at the time the study was devised (early 2011), gratitude tasks appeared to be the most well-tested. The only study to statistically compare the results of different positive wellbeing interventions (Sheldon & Lyubomirsky, 2006), suggested that there were no significant differences in positive affect from pre- to post-intervention when comparing the gratitude lists and BPS tasks.

Seligman et al (2005), utilized a number of different interventions which were not compared individually, but the authors commented that: "…participants in the *gratitude visit* condition showed the largest positive changes in the whole study" (p417). They also reported effect sizes for each intervention at each time point where the results differed significantly from the control. The effect sizes were low to moderate and roughly comparable across the different conditions. For example, effect sizes for the gratitude task (compared with control) for happiness were as follows: at post-test $\lambda^2 = .49$, at 1 week follow up $\lambda^2 = .39$ and at 1 month $\lambda^2 = .06$. For the original strengths task, at 1 week follow up $\lambda^2 = .07$, at 1 month $\lambda^2 = .42$, at 3 months $\lambda^2 = .33$ and at 6 months $\lambda^2 = .42$. The main difference here was not so much the magnitude of effect sizes but the latency of the effects to occur. Happiness increased greatly from pre- to post-intervention in the gratitude group and remained elevated until 1 month follow up. Effects of the strengths task were only seen by 1 week follow up (and not immediately post intervention), however these effects persisted for 6 months. Similarly, significant differences in happiness (compared with control) were only seen at the 1 month, 3 month and 6 month follow up time points for the '3 good things' task.

A few other studies (available in early 2011), also reported effects sizes. Emmons and McCullough (2003), noted small to moderate effect sizes for measures of wellbeing in gratitude task comparisons. For positive affect in study 2 (gratitude lists compared with lists of hassles), d= 0.36, and for positive affect in patients with neuromuscular disease (gratitude compared with no treatment in study 3), d= 0.56. The replication by Martinez-Marti et al (2010), reported slightly larger effect sizes: d= 0.69 for the increase in positive affect in the gratitude group compared with hassles. Finally, Cohen's d was 0.33 for the BPS task compared with control in Sheldon and Lyubomirsky (2006).

Thus, there was relatively little information available to assess the efficacy of the various positive interventions in relation to each other at the time our study was designed. Of the studies that did compare tasks, it generally seemed that either the gratitude task caused the biggest change in positive wellbeing or it did not matter which positive intervention task was used, because they were all equally effective. Indeed, Mongrain and Anselmo-Matthew's (2012) replication of Seligman et al (2005), found that the strengths task and a positive placebo task (recalling positive early memories) were roughly comparable. Another factor influencing the intervention choice was latency of effects. We were not planning to have follow up measures beyond immediate post-intervention, because there was not enough time available for such extensive testing and only enough money to process cortisol samples at 2 time points. Therefore, we could not use interventions that only came into effect several weeks after the task ended.

An additional consideration here is that several interventions listed in Table 8.1 were preliminary, e.g. Lyubomirsky et al (2005a), or exploratory, e.g. Seligman et al (2005) and Otake et al (2006). This is not necessarily a bad thing *per se*, but it seems that many of the original or early tasks have not been greatly developed; rather they have been partially or fully replicated in later studies without significant alteration. The frequency and duration of the interventions has been manipulated perhaps most extensively for the gratitude lists task, which may help to determine optimal delivery.

In conclusion, we decided to use the gratitude list task for our study, based on the reasoning that: i) it was relatively effective in eliciting short term increases in positive wellbeing, ii) could increase positive wellbeing rapidly (within 1 to 2 weeks), and iii) had been well-tested in comparison with the other methods. However, because the efficacy of this intervention was variable, we made several design choices to try to increase the success of the task which are outlined in the next chapter.

9 The Wellbeing Intervention Study

9.1 Introduction

Chapters 1 to 6 of this thesis presented evidence for associations between positive traits and a range of biological and psychological variables. However, to fully understand the links between positive wellbeing and health, it is necessary to explore causal pathways. As discussed in Chapter 8, the use of an intervention study may help us to identify such causal links by experimentally manipulating positive wellbeing. There have been very few studies assessing changes to biology following positive wellbeing interventions. It is not yet clear at this point whether the changes to biology seen in this small number of studies (such as reduction in blood pressure following meditation) are due specifically to improvements in positive wellbeing or due to other factors. Therefore, the current chapter aims to explore the effects of an intervention designed to increase positive wellbeing, on a selection of biological and psychological factors. Some of the results of this study have been published as a paper in the Journal of Health Psychology (Jackowska, Brown, Ronaldson, & Steptoe, 2015).

9.1.1 The gratitude intervention task

A gratitude based intervention was chosen for this study because it is one of the best-tested interventions, has easy practical application to a large number of participants and shows evidence of efficacy in increasing positive wellbeing within a short timeframe (see Chapter 8, section 8.3). We decided to use a slightly modified form of Emmons and McCullough's (2003) gratitude writing task, alongside a control writing task (writing about daily events) and a no treatment waiting list condition for comparison. The use of an active control condition as well as no treatment will help to determine whether any changes to wellbeing and biology are specifically due to the positive intervention (gratitude task) rather than from a placebo effect.

Many of the gratitude intervention studies reviewed in Chapter 8 (section 8.1.1) demonstrated post-intervention increases in measures of positive wellbeing such as positive affect and satisfaction with life. However, mechanisms explaining how gratitude interventions increase wellbeing have not been systematically tested (Wood, et al., 2010). As discussed in section 8.1.1, gratitude interventions do not necessarily work by increasing gratitude since not all studies found post-intervention increases in gratitude, although they did find increases in other measures such as positive affect. Wood et al (2010) suggest that expressing gratitude could improve wellbeing via specific mechanisms such as an increase in adaptive coping e.g. positive reinterpretation of problems, or by more general routes such as the experience of more frequent positive emotions. They also link gratitude to the Broaden and Build theory. The benefits of expressing gratitude, such as strengthening social bonds by feeling grateful towards others and the increase in positive feelings, are theorized to contribute toward the 'upward spiral' of positive affect suggested by Fredrickson (2001, 2004).

Since the driving mechanism for gratitude interventions is not yet fully understood, the current study includes a wide range of positive wellbeing measures including gratitude and questionnaire and daily measures of positive affect. It will be interesting to see whether gratitude increases in our study and indeed whether some or all measures of positive wellbeing will increase. The findings here will help to identify which positive wellbeing factors are important to the success (or otherwise) of gratitude interventions. If we are successful in increasing positive wellbeing, this may in turn impact on biology which will provide evidence of causal routes.

9.1.2 Study development and design considerations

The biological measures we decided to use in the study were cortisol, blood pressure and heart rate. As previously discussed, salivary cortisol is a useful non-invasive marker of both stress and health. The choice of biological variables was influenced by measures that we thought had scope to change within a relatively short amount of time. The Actiheart heart rate monitors were no longer available to use so unfortunately we could not assess HRV in this study. As an alternative, blood pressure and heart rate were assessed using ambulatory blood pressure monitors.

Blood pressure has been identified as one of the major risk factors for coronary heart disease, so may be more health relevant than other cardiac measures (Kannel, Schwartz, & McNamara, 1969; Pasternak, Grundy, Levy, & Thompson, 1996). There is also some evidence for associations between positive states and traits and blood pressure and heart rate, as mentioned in Chapter 1 (e.g. Jacob, et al., 1999; Steptoe, et al., 2007; Steptoe & Wardle, 2005). However, it should be noted that the direction of the results differed: for example, some studies reported an inverse association between positive wellbeing and blood pressure (e.g. Steptoe, et al., 2007), others reported a positive association (e.g. Jacob, et al., 1999) and yet other studies reported no association (James, et al., 1986; Steptoe, et al., 2005), therefore the findings remain mixed in this area. An additional issue is that the majority of positive wellbeing and blood pressure studies were cross-sectional, so causal mechanisms have yet to be established. However, there is growing evidence that meditation-based interventions, which are known to increase positive mood, may also reduce blood pressure (Goldstein, et al., 2012).

Because we wanted the intervention task to be as effective as possible, we decided to recruit participants who were likely to receive the most benefit from the task. We therefore aimed to select healthy female participants with some symptoms of mental distress (but without clinically diagnosed mental illness), since there is some evidence to suggest that people with lower positive affect tend to benefit the most from gratitude interventions (Froh, Kashdan, Ozimkowski, & Miller, 2009). As previously discussed in Chapter 3, women are more susceptible to depression and may have different patterns of HPA activity from men (Nolen-Hoeksema, 1990; Uhart, et al., 2006; Weiss, et al., 1999). Additionally, there are gender differences in blood pressure (Reckelhoff, 2001; Staessen et al., 1990). Having a more homogenous sample was advantageous for such a complex study because it could reduce variability between participants. Therefore, we decided to test only women for theoretical as well as practical reasons.

The study design and data collection were completed in collaboration with another PhD student (Ms. Marta Jackowska), who was investigating sleep. Therefore, design considerations have been made to include sleep-related measures. These are mentioned briefly in the method but the results are not reported in this thesis to avoid overlap.

9.1.3 Aims and hypotheses

The Wellbeing Intervention Study was specifically designed to test whether changes in positive wellbeing were associated with changes to biology. The study aimed to improve the mental wellbeing of healthy women by using a gratitude intervention task. If there were improvements to positive wellbeing *and* changes to biology, we hoped to make causal inferences about the association between mental and physical wellbeing. Our hypotheses were as follows:

1. Participants in the gratitude condition will show greater improvements in positive wellbeing and/or mental health from pre- to post-intervention than those randomised to the comparison conditions.

2. Biological measures of participants in the gratitude condition may change from pre- to post-intervention, most likely seen as reductions in blood pressure and cortisol output and/or steeper cortisol slopes.

The direction of any changes in the biological measures was difficult to predict considering the wide disparity in findings for associations between positive wellbeing and biology. However, we reasoned that overall, studies of positive wellbeing and cortisol have suggested an inverse relationship; therefore any increases in positive wellbeing following the intervention task would most likely be associated with decreases in cortisol. As for blood pressure, other interventions have reported reduced blood pressure following meditation, so if our intervention is similarly effective then the results may follow the same pattern. The direction of change for heart rate was the most difficult to predict because there was little evidence for an association between positive wellbeing and heart rate in women (as discussed in Chapter 1). However, we suggest that if heart rate does change following the gratitude task, it will most likely decrease. This is based on the reasoning that completing a positive wellbeing task may help to reduce depression and stress (as found in a number of interventions outlined in Chapter 8), thereby potentially increasing parasympathetic nervous influence and/or reducing sympathetic influence, resulting in reduced heart rate.

9.2 Method

9.2.1 Participants

9.2.1.1 Screening and recruitment

Participants were recruited via e-mail, online newsletter and poster from UCL and Birkbeck, University of London. During recruitment, potential participants were told that the study may involve a task aimed at increasing wellbeing and that a number of psychological and biological measures were included (see participant information sheet, appendix 5). We therefore expected to recruit people who were particularly interested in improving their mental wellbeing. Ethical approval for the study was granted from the UCL ethics board.

Potential participants were screened using an online questionnaire which included the 12-item General Health Questionnaire (GHQ-12, Goldberg & Williams, 1988), the Jenkins Sleep Problems scale (Jenkins, et al., 1988), and personal information such as illness history and medication use. The screening questionnaires were chosen with the aim to select participants with some symptoms of emotional distress (but without clinically diagnosed mental illness), and mild to moderate sleep problems, but were otherwise healthy. We reasoned that people experiencing emotional distress would have more scope to improve their positive wellbeing compared to people who were already very happy. Likewise, people with mild to moderate sleep problems would have scope to improve their sleep.

The GHQ is well validated and has been used as a short screening instrument for psychiatric morbidity in epidemiological studies and in primary care settings (Goldberg, Oldehinkel, & Ormel, 1998; Henkel et al., 2003; Mitchell & Coyne, 2009). It has a good specificity for depression but can also be used as a more general screening instrument to detect non-psychotic mental health problems (Goldberg & Williams, 1988). The GHQ-12 includes questions such as ‘Have you recently been feeling unhappy or depressed?’ with 4 response options to indicate relative frequency of experiencing each item over the last few weeks from ‘Not at all’ to ‘Much more than usual’. The GHQ was scored using the standard binary method as described in the scale handbook (Goldberg & Williams, 1988). Items experienced as either ‘Not at all’ or ‘No more than usual’ were scored as 0 and responses of ‘Rather more than usual’ or ‘Much more than usual’ were scored as 1. Previous research suggests that scores above 2 are associated with the possibility of case level symptoms of mental illness according to established psychiatric criteria (Goldberg et al., 1997; Goldberg, et al., 1998; Goldberg & Williams, 1988). Scores of 9 or above have been associated with meeting diagnostic criteria for clinical level depressive and anxiety disorders (Baksheev, Robinson, Cosgrave, Baker, & Yung, 2011; Politi, Piccinelli, & Wilkinson, 2007). Therefore the screening criteria for the GHQ had a lower and upper limit in this study to avoid recruiting women with either very little or very high levels of emotional distress.

Women were invited to take part in the study if they met all of the following selection criteria: i) aged between 18 and 45, ii) either postgraduate students or workers, iii) scored between 2 and 9 on the GHQ-12, iv) scored between 1.75 and 4 on the Jenkins Sleep Problems scale, v) did not have a history of serious mental health issues (including clinical depression) or physical illness within the last 2 years, vi) were not pregnant and vii) were not taking any medication (including antidepressants) except for the contraceptive pill. The age range was chosen since cortisol regulation, blood pressure and sleep patterns tend to differ with age, particularly after middle age for sleep (e.g. Franklin et al., 1997; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004; Van Cauter, et al., 1996). Pregnancy and the use of medications may affect cortisol and cardiac measures, as reported in Chapter 3 (e.g. Aloisi, et al., 2011; Demey-Ponsart, et al., 1982; Licht et al., 2009; Pariante, et al., 2004; Voss, et al., 2000).

9.2.1.2 Participants and study attrition

A target sample size of 120 participants (40 in each group) was estimated following sample size calculations with 85% power ($\alpha = 0.05$). This calculation was based on the post-intervention data for positive affect in study 2 of Emmons and McCullough (2003), where there was a significant difference in positive affect between the gratitude and hassles group with a small to moderate effect size.

There was a good initial response to the study advert with 916 potential participants completing the screening questionnaire. However, only 244 women were eligible for the study (see Figure 9.1 which details recruitment and participant loss). The main reason for ineligibility was not meeting the screening questionnaire requirements. Of the eligible participants, 125 women were not recruited to the study because we were unable to re-contact them, they no longer wished to take part or because they did not attend the first meeting (and were not able to reschedule).

119 healthy female participants were recruited to the study with mean age of 26.3 years old (SD 4.87). 40 participants were allocated to the gratitude condition, 41 to the daily events condition and 38 to the waiting list condition. 4 participants dropped out of the study after completing the first week due to an unexpected trip (N=1), discomfort with the biological monitoring equipment (N=1) and unknown reasons (N=2). Therefore, 115 participants completed the study with 39 participants each in the gratitude and daily events groups and 37 in the waiting list group. The overall attrition rate due to participant withdrawal was 2.5% in the gratitude condition, 4.9% in the daily events condition and 2.7% in the waiting list condition.

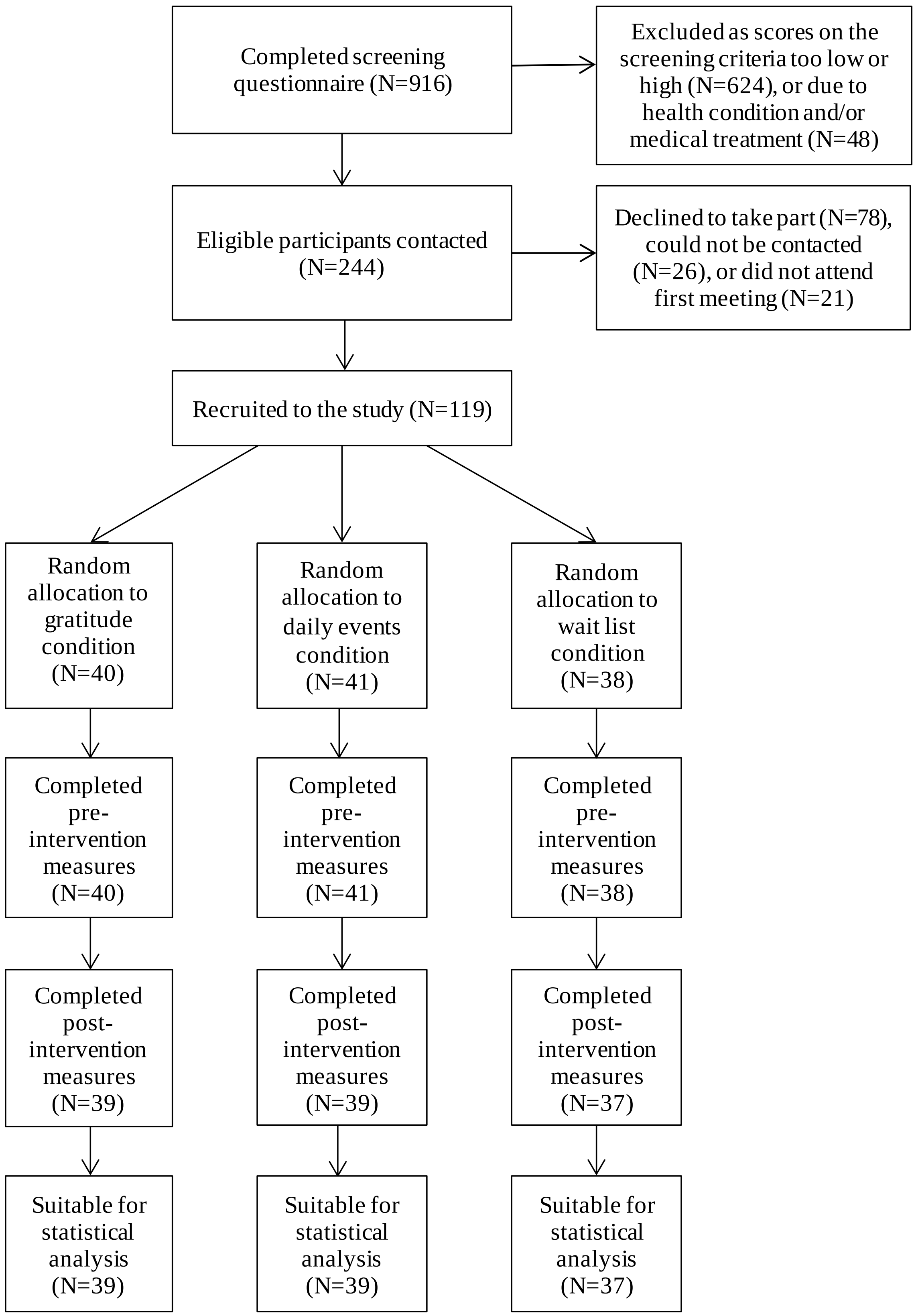


Figure 9.1: Recruitment and attrition by condition

9.2.2 Design

This was a single blind randomized controlled trial where the participants were blind to the writing condition but the researchers were not. This was because part of the procedure involved explaining how to complete the writing tasks and asking the participants to complete an example to check they had understood the instructions. Participants were randomly assigned to one of the three conditions: the gratitude writing task, the daily events writing task or received no intervention task (waiting list).

9.2.3 Materials and measures

9.2.3.1 Psychological, demographic and health behaviour questionnaire measures

The participants were given a questionnaire booklet before and after the intervention which assessed a range of psychological, demographic and health behaviour measures (listed in Table 9.2). The psychological measures were selected to cover a range of positive wellbeing and mental health factors, which we thought may have scope to change during the intervention. Resilience was not assessed because we had no reason to believe that it would change within the relatively short 2 week intervention period and the gratitude task was not designed as a resilience intervention.

For scales where the instructions included a temporal aspect (i.e. ratings of frequency), the participants were asked to consider how they had felt over the past *week*. This was so that the measures would be more sensitive to the short term changes that might occur during the study (the original instructions for scales with a temporal aspect typically assessed feelings over several weeks to a month).

Table 9.2: List of measures used in the study. Measurements were taken at both baseline (pre-intervention) and post-intervention unless otherwise stated

Measurement type	Measurement	Materials	Details/references
Demographic*	Age, income, marital status, parental status, ethnicity, education, employment & working hours	Self-devised questionnaire (multiple choice questions)	See appendix 6, section 1
Health behaviour*	Physical activity	Frequency of physical activity	Marmot et al (1991)
	Smoking	Self-devised questionnaire	See appendix 6, section 2
	Alcohol intake	Self-devised questionnaire	See appendix 6, section 2
Affect/positive wellbeing	Positive and negative affect	Scale of Positive and Negative Experience (SPANE)	Diener et al (2010)
	Gratitude	The Gratitude Questionnaire – 6 (GQ6)	McCullough et al (2002)
	Optimism	Life Orientation Test Revised (LOT-R)	Scheier et al (1994)
	Life satisfaction	Satisfaction with Life Scale (SWLS)	Diener et al (1985)
	Flourishing	The Flourishing Scale	Diener et al (2010)
Mental health	Perceived stress	Perceived Stress Scale (PSS)	Cohen et al (1983)
	Depression and anxiety	Hospital Anxiety and Depression Scale (HADS)	Zigmond & Snaith (1983)
Physical wellbeing	Self-rated physical health	Single question measure	See last question in appendix 6

	Self-reported sleep quality	*Pittsburgh sleep quality index*	*Buysse et al (1989). Results not reported in this thesis*
Daily measures	Positive and negative affect	Positive and Negative Emotional Style (modified)	Cohen et al (2003). See appendix 7
	Daily stress	Stress-related adjectives were included with the daily affect measures	See appendix 7
	Typicality of the day	Single question assessing how typical each day was compared to a 'normal day'	See appendix 7
	Self-reported sleep duration & quality	*Self-devised questionnaire*	*Not reported in this thesis*
Biological	Salivary cortisol	Cotton swabs and salivettes	Samples collected at 7 time points over 24 hours
	Blood pressure	Ambulatory blood pressure monitor (Spacelabs Inc.)	Measurements taken every 30 minutes across one day
	Heart rate	Ambulatory blood pressure monitor (Spacelabs Inc.)	Measurements taken every 30 minutes across one day
	Objective sleep duration	*Ambulatory activity monitor (Actigraph)*	*Not reported in this thesis*
Writing task compliance**	Task completion & effort	Self-devised questionnaire	See appendix 8

*Measured at baseline only

**Measured post-writing task only

Note: *measures in italics were included in the study but not reported as part of this thesis*

9.2.3.1.1 Demographic information and health behaviour measures

Demographic and health behaviour questionnaire measures were only taken before the intervention as these were thought to remain relatively constant within the course of the study, so only needed to be measured once. Detailed demographic information was collected and later divided into binary categories as follows: personal income (<£15,000 or £15,000 or more), household income (<£20,000 or £20,000 or more), marital status (single/divorced or married), parental status (no children or has children), ethnicity (white or non-white ethnicity), education (<postgraduate degree or postgraduate degree), employment (postgraduate student or other jobs) and working hours (≤34 hours or 35 hours or more). Health behaviour measures were similar to the Daytracker study and included physical activity (Marmot, et al., 1991), smoking and drinking behaviour (see appendix 6, section 2). Exercise frequency was divided into binary categories (<once a week and once a week or more) for mild, moderate and vigorous exercise separately.

9.2.3.1.2 Questionnaire measures of positive wellbeing, affect and mental health

A number of different scales were included to capture various aspects of positive wellbeing including the Gratitude Questionnaire (GQ6, McCullough, et al., 2002), the Life Orientation Test (LOT-R, Scheier, et al., 1994), the Satisfaction with Life Scale (SWLS, Diener, et al., 1985) and the Flourishing Scale (FS, Diener, et al., 2010). Positive and negative affect were assessed using the Scale of Positive and Negative Experience (SPANE, Diener, et al., 2010).

A measure of gratitude was included to see whether the intervention writing task did indeed improve gratitude. Accordingly, the most relevant gratitude scale was the GQ6 (McCullough, et al., 2002), as it was devised by the same authors as the gratitude writing task. The GQ6 includes 6 statements reflecting aspects of a grateful disposition, to which participants rate each item from *1 = strongly disagree* to *7 = strongly agree.* The scale has a good convergent validity and internal consistency with a Cronbach's α of 0.82 (McCullough, et al., 2002). The LOT-R and the SWLS are both standard measures for assessing both optimism and satisfaction with life (respectively) and have been used extensively in psychological studies over many years.

The SPANE and the FS (Diener, et al., 2010), are relatively new questionnaires, but were selected as they are both brief and offer several advantages over more traditional measures. The SPANE consists of 12 items: 6 positive and 6 negative. For each type of affect (positive or negative), there are 3 general adjectives describing feelings (such as 'positive', 'pleasant' or 'negative') and 3 specific items (e.g. 'joyful' or 'sad'). Participants are asked to rate each item for the frequency with which they have felt each item from *1 = very rarely or never* to *5 = very often or always*. The PANAS (Watson, et al., 1988), which is commonly used for measures of affect, has been criticized for including only high arousal emotions, items which may not be considered emotions such as 'active' and 'strong', and items which may be culturally unique (particularly to Western cultures). The SPANE offers advantages such as: measuring all levels of arousal, including general as well as more specific feelings, and being less culturally specific compared with the PANAS (Diener, et al., 2010). Also, assessments of affect frequency may be more strongly associated with wellbeing than measures of intensity (Diener, Sandvik, & Pavot, 1991). The SPANE has good psychometric properties including good internal reliability, temporal stability and convergent validity with other similar measures such as the PANAS and Subjective Happiness Scale (Lyubomirsky & Lepper, 1999). The Cronbach's α in a study of 689 college students was 0.87 for positive affect and 0.81 for negative affect (Diener, et al., 2010).

The Flourishing Scale (FS) consists of 8 positively worded statements to which participants rate how much they agree with each item from *1 = strongly disagree* to *7 = strongly agree.* The items of the FS were developed to cover major facets of social and psychological wellbeing and include aspects relating to social relationships, purpose and meaning in life, engagement with activities, self-respect, optimism and self-competence. Thus, the FS covers many different characteristics of positive wellbeing whilst being relatively brief. The FS also has good reliability and validity with a Cronbach's α of 0.87 (Diener, et al., 2010).

Measures of mental health included the Perceived Stress Scale (PSS, Cohen, et al., 1983) and depression and anxiety from the Hospital Anxiety and Depression Scale (HADS, Zigmond & Snaith, 1983). Again, the PSS and HADS are standard measures of stress and mental health (respectively), which have been well validated. There was also a single question on physical health taken from the Daytracker study where participants were asked to rate their health on a five point Likert scale from *poor* to *excellent* (see end of appendix 6, question 15).

9.2.3.2 Daily measures

In addition to the questionnaire booklet, there was also a daily measures diary which assessed affect, stress and day typicality every day for 7 days (see appendix 7). Again, these measures were taken before and after the intervention. Daily affect was assessed using items selected from the Positive and Negative Emotional Style scales (or PES and NES, as described in Cohen, et al., 2003). This scale is similar to the PANAS in that it lists emotion-related adjectives (9 positive and 9 negative), and participants are asked to rate how much they felt each emotion from *very slightly/ not at all* to *extremely*. The scale was originally constructed to represent examples from within 3 sub-categories of positive emotions (vigour, wellbeing and calm), and 3 sub-categories of negative emotions (depression, anxiety and hostility), with 3 adjectives for each sub-category. The scale was based on a factor analysis of affect related adjectives by Usala and Hertzog (1989), which was subsequently modified by Benyamini, Leventhal and Leventhal (2000). Cronbach's α values for this scale ranged from 0.87 to 0.93 (Benyamini, et al., 2000; Cohen, et al., 2003). We decided to use the PES and NES considering the criticisms of PANAS as previously mentioned and because we did not want to use SPANE again since this was used to measure affect in the questionnaire booklet.

The PES and NES scale was modified (shortened) for this study to reduce participant burden. We selected 6 positive and 6 negative words from the original list, 2 from each of the sub-categories of emotion. The selected positive words were: 'lively' and 'energetic' (from the vigour sub-category), 'happy' and 'cheerful' (wellbeing sub-category) and 'at ease' and 'calm' (calm sub-category). The negative words were: 'sad' and 'unhappy' (depression sub-category), 'on edge' and 'tense' (anxiety sub-category) and 'hostile' and 'angry' (hostility sub-category). The words were selected based on their frequency of use in the English language (e.g. 'lively' is used more often than 'full-of-pep'), or because they were better representatives of their sub-category (e.g. 'angry' was deemed to be a better representation of the sub-category 'hostile' compared to the word 'resentful').

A list of items to be rated on a daily basis was constructed by presenting the 12 selected emotional words along with 2 stress-related adjectives ('stressed' and 'hassled') and 2 sleep-related adjectives ('tired' and 'fatigued'), in a random order (see appendix 7). The participants were asked to rate how much they felt each of the items during the day from *very slightly/ not at all* to *extremely*.

A single question ('Was today a normal day for you?') was used to assess how typical each day was for the participants, as part of the daily measures (see appendix 7).

9.2.3.3 Biological measures

The biological measures included cortisol, blood pressure and heart rate which were taken over waking hours. There was also an objective measure of sleep duration using actigraphy (the results are not reported in this thesis).

9.2.3.3.1 Cortisol

Salivary cortisol samples were taken at 7 time points across a 24 hour period both before and after the intervention, using salivettes. The samples were taken: 1) during the laboratory visit (at a variable time before 10am), 2) at 10am, 3) 12pm, 4) 5pm, 5) bedtime the same day, 6) upon waking the next morning and 7) 30 minutes after waking. The salivettes were numbered from 1 to 7 to reflect each sample time in chronological order. Because the first saliva sample was taken at a variable time during the lab visit and was intended as a practice, the results from these samples were not included in the analyses.

As in the Daytracker study, participants were asked to fill out a saliva sample diary for each sample (see appendix 9). The saliva diary included detailed instructions, questions on the exact time the sample was taken, whether there had been a delay between waking and taking the waking sample, whether or not they had brushed their teeth, eaten a meal, drank a caffeinated or alcoholic beverage, smoked, exercised or taken any medication within the 30 minutes prior to taking the sample. There were also ecological momentary assessments (EMA) of mood (happiness, sadness, frustration/anger), stress and tiredness included in the saliva collection diary for each sample. The results of the EMA assessments are not reported in this thesis.

9.2.3.3.2 Blood pressure and heart rate

Blood pressure and heart rate were assessed pre- and post-intervention using ambulatory blood pressure (ABP) monitors (Spacelabs Inc.). These ABP monitors consisted of an inflatable arm cuff attached via a long rubber tube to a recording device in a protective case worn around the waist on a belt. The recording device was programmed using Spacelabs software to take a reading every 30 minutes across one day. Recording started after the monitor was fitted during the lab visit (before 10am) and continued until bedtime the same day, when the participants were asked to remove the unit. The readings were not visible to the participants. There was a space at the back of the saliva sample diary to record times when the unit had been removed (see appendix 9). The blood pressure units are accurate to -1±7 mmHg for systolic and -3±6 mmHg for diastolic blood pressure (O'Brien, Mee, Atkins, & O'Malley, 1991).

9.2.3.4 The writing tasks

9.2.3.4.1 Gratitude writing task

The gratitude intervention task was devised using a similar method to Emmons and McCullough (2003) and Sheldon and Lyubomirsky (2006). Participants assigned to this condition were asked to write about 3 things, large or small, for which they were grateful. This was repeated 3 times a week for 2 weeks (making 6 gratitude exercises in total). The task was presented in a booklet with written instructions on the first page, followed by a blank box for the participants to fill out a practice example. The rest of the booklet comprised of 6 blank boxes for each gratitude exercise. Each box was marked on the left hand side with numbers 1 to 3 indicating spaces for the 3 gratitude sentences. A copy of the task booklet can be found in appendix 10 and the instructions for the task are given below. Note: the paragraphs marked with asterisks are taken verbatim from Sheldon and Lyubomirsky (2006), p 76.

> **You have been randomly assigned to try to cultivate a sense of gratitude now, and during the next few weeks. 'Cultivate a sense of gratitude' means that you make an effort to think about the many things in your life, both large and small, that you have to be grateful for. These might include particular supportive relationships, sacrifices or contributions that others have made for you, facts about your life such as your advantages and opportunities, or even gratitude for life itself, and the world that we live in.*
>
> *For example: I am grateful....'To my husband for paying me a compliment on my new dress', 'That I found the strength to deal with a difficult situation at work', 'That I finally cleaned my flat', 'For the kindness of my parents', 'I am grateful that the trees are finally green', 'I am grateful I was given a seat in the bus this morning', 'I am grateful my cat is no longer unwell', 'After watching this evening news I am grateful I live in a peaceful country'...*
>
> **In all of these cases you are identifying previously unappreciated aspects of your life, for which you can be thankful. You may not have thought about yourself in this way before, but research suggests that doing so can have a positive effect on your mood and life satisfaction.*
> *We'd like you to practice writing an example of something you are grateful for in your life. [Text box for practice exercise here]*
>
> *When you get home, we'd like you to write about 3 things you are grateful for. We would like you to do this 3 times per week. You should spread out your writing exercises e.g. every other day such as Monday, Wednesday, Friday. We would like you to do this for 2 weeks (6 writing exercises in total). Please try to write something different every time.*
> *We have provided boxes for you to write your sentences on the next 2 pages, you do not have to fill the entire space. Please provide the day of the week you completed each exercise, so that you can keep track.*

9.2.3.4.2 Daily events writing task

The daily events writing task was intended as an active control condition for comparison with the gratitude task and was matched as closely as possible to make a convincing placebo. The task involved writing about 3 daily events 3 times a week over the 2 week writing period, therefore the construction of the writing booklet was identical to the gratitude writing task, apart from some differences in the instructions. We devised the task to be fairly neutral in content following similar placebo tasks such as the 'life events' condition in Emmons and McCullough (2003) and the 'life details' control in Sheldon and Lyubomirsky (2006). The writing booklet for this condition can be found in appendix 11, and the instructions were as follows (text in bold differs from the instructions for the gratitude task):

> ***You have been randomly assigned to write about events that have happened during your day. We want you to start focusing your attention on everyday events, and become more aware of what is happening around you. For example, on your way to work instead of rushing to a bus stop, or a train station, try not to think about or plan your day, but pay attention to your surroundings. Perhaps listen if birds are singing, look at the flowers in people's front gardens, or just simply observe the things around you***. *You may not have thought about yourself in this way before, but research suggests that doing so can have a positive effect on your mood and life satisfaction.*
>
> ***For example, today I noticed….'The wind rustling in the trees', 'The colours of the flowers', 'My neighbour's children playing in the garden', 'The noise of the traffic', 'The first signs of autumn', 'The smell of grass after the rain', 'Other people talking in the train', 'The building opposite my office was being cleaned'.***
>
> *We'd like you to practice writing an example of an event that happened today.*
> *[Text box for practice exercise here]*

*When you get home, we'd like you to write about **3 different events that happened that day**. We would like you to do this 3 times per week. You should spread out your writing exercises e.g. every other day such as Monday, Wednesday, Friday. We would like you to do this for 2 weeks (6 writing exercises in total). Please try to write something different every time.*

We have provided boxes for you to write your sentences on the next 2 pages, you do not have to fill the entire space. Please provide the day of the week you wrote your exercise, so that you can keep track.

9.2.3.5 Writing task compliance

Self-reported measures of writing task completion and effort were collected by asking the participants how many days they had completed their writing task (from *once* to *6 times* across the 2 weeks), and how much effort they had put into the task (from *Very little effort* to *Quite a bit of effort* to *A lot of effort*). These measures were included at the end of the post-intervention questionnaire booklet (see appendix 8).

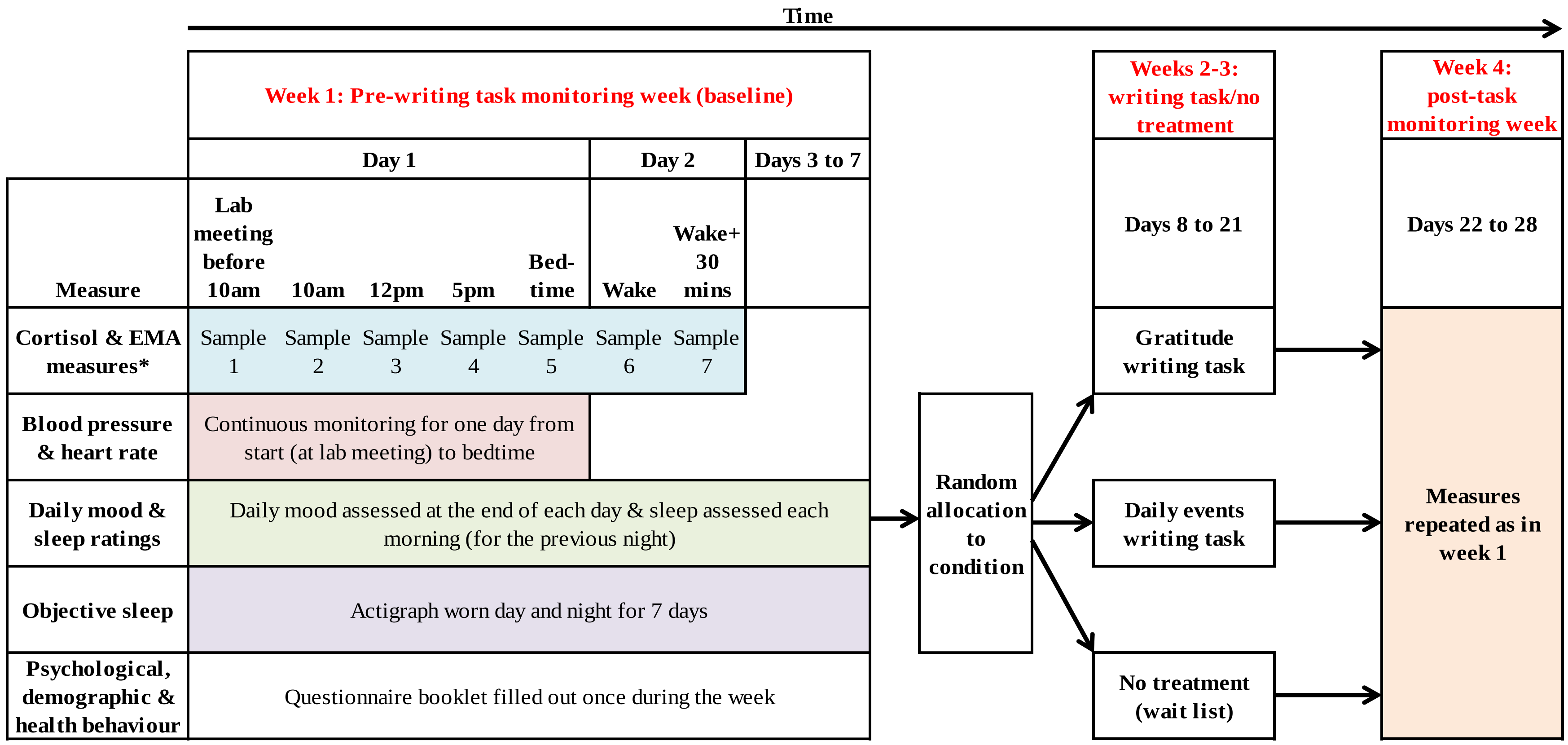
9.2.4 Procedure

The procedure for each participant took 4 weeks: the first week was a baseline monitoring week, the writing task was completed during weeks 2 to 3 and week 4 was a post-intervention monitoring week (the same as week 1). Figure 9.3 shows the progression of each phase of the study as a timeline.

9.2.4.1 Week 1: Baseline monitoring week (pre-intervention)

Potential participants were screened using an online questionnaire (as previously described); those meeting the criteria were invited to take part in the study. On the first day of the study the participants attended a short laboratory meeting (about 30 minutes) before 10am Monday to Thursday (so that all cortisol and blood pressure measures were during the working week). Participants were assigned consecutive numbers according to the order in which they attended the first laboratory meeting.

During the meeting, the procedure was explained and informed consent was obtained. Height and weight measurements were taken (to calculate BMI) and details on menstrual cycle and use of contraceptive medication were collected. The participants took their first saliva sample (as a practice), filled out the first page of the saliva sample diary and were given a bag of 6 salivettes to collect the rest of the samples over the next 24 hours. A measure of resting blood pressure was taken using a static blood pressure monitor as a reference point. Following this, ambulatory blood pressure (ABP) cuffs were fitted to the participant's arm (on the side not used for writing). The monitoring units were connected to the cuff, switched on, placed into a protective case on a belt around the waist and tested.



*EMA = Ecological momentary assessment of mood (results not reported in this thesis)

Figure 9.3: Timeline showing the order of events in the study procedure

An Actigraph activity monitor was also fitted to the wrist during the lab visit. The side on which the ABP cuffs and Actigraphs were fitted was recorded so that post-intervention fittings were made on the same side. The participants were given a folder containing detailed instructions on the study and equipment, a questionnaire pack, a daily mood and sleep diary and the saliva sample materials (salivettes and sample diary). At the end of the lab visit, arrangements were made to collect the saliva samples, sample diary and ABP monitors the next day. An appointment was made for 7 days time to collect the Actigraph devices and to give out the next part of the study for participants in either of the writing task conditions.

The participants wore the ABP monitor from the lab visit until bedtime the same day (when they had been instructed to remove the monitor and turn it off) and proceeded to take the next 6 saliva samples at the allotted times over the same day and next morning. The ABP monitor, saliva samples and saliva diary were collected the day after the lab visit (or as soon as possible thereafter). The saliva samples were immediately transferred to a freezer and then couriered to a laboratory for cortisol extraction via immunoassay (Technical University, Dresden, Germany).

Daily mood, stress and sleep measures were collected at the end of each day for 7 consecutive days (including the start day). The Actigraph was also worn for 7 consecutive days both day and night to record activity and sleep. The questionnaire booklet was filled out once during the first monitoring week. The participants were sent a reminder mid-way during the first week to continue filling out the daily mood and sleep diary and to complete their questionnaire booklet (if they had not done so already). At the end of the first week, the Actigraph, questionnaire booklet and daily mood diary were collected and the writing task was handed out and explained.

9.2.4.2 Weeks 2 to 3: Writing task

After completion of the first monitoring week, the participants were assigned to either the gratitude task, the daily events task or to no treatment (waiting list) according to a randomization sequence determined using an online random number calculator (www.random.org). Instructions for completing the writing tasks were explained orally and in writing (on the first page of the writing booklet) and the participants were asked to fill out a practice example to check they had understood the instructions. Over the next 2 weeks, the participants completed their gratitude or daily events exercises 3 times a week (6 exercises in total). An e-mail reminder was sent in the middle of each of the 2 weeks to encourage the participants to continue the task and to arrange the next lab meeting. Participants in the waiting list condition were sent an e-mail to arrange the next meeting only.

9.2.4.3 Week 4: Post-intervention monitoring week

After completing the writing task or waiting for two weeks in the no treatment group, the participants attended a final lab visit where the procedure for the baseline monitoring week was repeated. The final lab visit was shorter (about 15 minutes) because height and weight were not measured and the procedure was not explained again unless requested by the participant. As in week 1, the participants collected saliva samples, filled out a saliva sample diary and wore a blood pressure monitor on the first day of the monitoring week. They completed daily affect and sleep measures and wore an Actigraph for one week. Additionally, the post-intervention questionnaire booklet was completed during the week. At the end of week 4 the participants were fully debriefed and received a small honorarium for their time. The participants in the waiting list condition were then given access to the gratitude task if they wished to try it, but were not followed up further.

9.2.5 Scoring and data analysis

9.2.5.1 Psychological questionnaire measures

Apart from the Scale of Positive and Negative Experience (SPANE), all other psychological scales were scored as indicated by the original references (see Table 9.2) both before and after the intervention. Mean scores were calculated for the SPANE which could range from 1 to 5. For all psychological scales, higher scores indicated greater or more frequent measures. For example higher scores on the gratitude scale indicated greater levels of gratitude, higher scores on the Perceived Stress Scale indicated greater levels of stress.

9.2.5.2 Daily measures

Mean daily scores were calculated for positive emotional style, negative emotional style and stress for each participant over each day, during the pre and post-task monitoring weeks, and could range from 0 to 4. For each participant, the daily mean scores were then averaged across the 7 monitoring days. Data from a minimum of 3 monitoring days was required to calculate the mean affect and stress values across the pre- and post-monitoring periods separately.

9.2.5.3 Cortisol

Three cortisol measures were calculated for each participant, both before and after the intervention: 1) cortisol awakening response (CAR), 2) total cortisol calculated as area under the curve (AUC) and 3) cortisol slope. The CAR (nmol/l) was calculated as the cortisol increase (CAR_i = wake+30 concentration - waking concentration), as described by Pruessner and Hellhammer (2003b). The CAR was only calculated if the following conditions were fulfilled: 1) the wake+30 sample was taken at ≤45 minutes after the waking sample, and 2) any delay between waking and taking the waking sample was ≤15 minutes (following Dockray, et al., 2008; Edwards, et al., 2001; Schmidt-Reinwald, et al., 1999). This calculation of CAR was designed to omit cases with large discrepancies in timing.

Total cortisol was calculated using the area under the curve with respect to ground (AUC_G) method (Pruessner, et al., 2003a). Logged values (using natural log), were used for the total cortisol scores as they were not normally distributed. Cortisol slope was calculated as the regression slope of the daily change in cortisol concentration (nmol/l/min) across all samples including the waking value. The methods for calculating total cortisol and cortisol slope are detailed in Chapter 5 (section 5.2.1).

Missing samples were treated as missing because participants with incomplete samples pre-intervention had 3 or more samples missing each. This would have made it difficult to accurately impute missing values. Additionally, we did not want to impute values for missing post-intervention samples in case this misrepresented any effects of the intervention.

9.2.5.4 Blood pressure and heart rate

The blood pressure and heart rate data was downloaded from the ABP units using Spacelabs software. This software gives a list of blood pressure and heart rate values for each reading, with zero values where a valid reading was not obtained (for example where the participant was moving during cuff inflation). The data was manually checked for any anomalies.

As a guideline for identifying potentially anomalous readings for particularly high blood pressure, systolic blood pressure readings >70mmHg and diastolic readings >20mmHg above each participant's resting blood pressure (taken in the lab) were examined on an individual basis to account for changes in blood pressure during exercise (Palatini, 1988; Pickering, Harshfield, Kleinert, Blank, & Laragh, 1982; Sung et al., 2003). For low blood pressure, readings <50mmHg systolic and <40 mmHg diastolic blood pressure were examined individually, based on indicators of particularly low blood pressure as used in Gellman et al (1990).

Participants with missing data tended to have missing values over several hours, making it difficult to accurately impute missing values. Missing data was therefore treated as missing. Mean systolic and diastolic blood pressure (in mmHg) and heart rate (in beats per minute or BPM) were calculated across the entire monitoring day both before and after the intervention weeks.

9.2.6 Statistical analysis

One way ANOVAs and chi squared tests were conducted as appropriate to look for any significant differences between the groups in any of the demographic and health behaviour variables or in any of the baseline measures. The change from baseline to post-intervention for all variables was calculated as differences scores (post-intervention score minus baseline score). One way analyses of covariance (ANCOVA) adjusted for age and baseline values were conducted for the difference scores for each of the questionnaire and daily psychological variables. For the blood pressure and heart rate difference scores, the ANCOVAs were adjusted for age, BMI and baseline value. The ANCOVAs for the cortisol data were additionally adjusted for pre-intervention waking time. Covariates were kept to a minimum to avoid over adjustment of the models. Age has been associated with positive wellbeing and the biological variables in this study (Franklin, et al., 1997; Stone, Schwartz, Broderick, & Deaton, 2010; Van Cauter, et al., 1996). BMI is related to both cortisol and blood pressure (Doll, Paccaud, Bovet, Burnier, & Wietlisbach, 2002; Fraser, et al., 1999; Lamon-Fava, Wilson, & Schaefer, 1996) and waking time has also been associated with cortisol, as mentioned in Chapter 5 (section 5.2.2), so these three covariates were included.

9.2.7 Pilot study

A pilot study was conducted to test the usability of the procedure and writing tasks. There were 8 participants including 5 women and 3 men. Four participants were randomly assigned to the gratitude condition and 4 to the daily events condition. The procedure was carried out as previously described except for the cortisol measures and participant screening. Following feedback from the pilot participants, minor adjustments were made: i) to the wording of the writing task instructions (including the addition of a greater number of examples), ii) to the design of the questionnaire booklet and iii) to the design of the daily mood and sleep diary.

9.3 Results

9.3.1 Demographic variables & health behaviour

Participant characteristics across all participants and by condition can be seen in Table 9.4. The majority of the participants earned less than £15,000 individually and more than £20,000 as a household, were single/divorced, did not have children and were white. Most participants were postgraduate students, had a level of education less than postgraduate degree and worked 35 hours or more per week. The mean age of the participants was 26.3 years old (SD 4.87).

The majority of the participants were non-smokers, engaged in mild exercise more than once a week, and moderate and vigorous exercise less than once a week. Most participants drank alcohol, with a mean alcohol consumption of 10.7 (SD 8.94) drinks per fortnight. According to chi squared and one way ANOVAs there were no significant differences between the groups in any of the demographic variables or health behaviour measures (p values ranged from .172 to .876).

Table 9.4: Demographic (a) and health behaviour (b) characteristics of the participants as a whole and by condition

(a)

Demo-graphic variables	Category	All participants N(%)	Gratitude condition N(%)	Daily events condition N(%)	Wait list condition N(%)
Personal income	<£15,000	72 (61.5%)	23 (59%)	26 (65%)	23 (60.5%)
	£15,000 or more	45 (38.5%)	16 (41%)	14 (35%)	15 (39.5%)
Household income	<£20,000	49 (41.2%)	14 (35%)	18 (43.9%)	17 (44.7%)
	£20,000 or more	70 (58.8%)	26 (65%)	23 (56.1%)	21 (55.3%)
Marital status	Single/divorced	77 (65.8%)	25 (65.8%)	29 (70.7%)	23 (60.5%)
	Married	40 (34.2%)	13 (34.2%)	12 (29.3%)	15 (39.5%)
Parental status	No children	114 (95.8%)	38 (95%)	39 (95.1%)	37 (97.4%)
	Has children	5 (4.2%)	2 (5%)	2 (4.9%)	1 (2.6%)
Ethnicity	White	86 (72.3%)	27 (67.5%)	31 (75.6%)	28 (73.7%)
	Non white ethnicity	33 (27.7%)	13 (32.5%)	10 (24.4%)	10 (26.3%)
Education	<Postgraduate degree	68 (57.1%)	23 (57.5%)	22 (53.7%)	23 (60.5%)
	Postgraduate degree	51 (42.9%)	17 (42.5%)	19 (46.3%)	15 (39.5%)
Employ-ment	Postgraduate student	103 (86.6%)	35 (87.5%)	36 (87.8%)	32 (84.2%)
	Other jobs	16 (13.4%)	5 (12.5%)	5 (12.2%)	6 (15.8%)
Working hours	≤ 34 hours	53 (46.1%)	18 (45%)	19 (50%)	16 (43.2%)
	35 hours or more	62 (53.9%)	22 (55%)	19 (50%)	21 (56.8%)
		Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
	Age	26.3 (4.87)	26.6 (4.80)	26.8 (5.00)	26.0 (4.87)

(b)

Health behaviour	Category	All participants N(%)	Gratitude condition N(%)	Daily events condition N(%)	Wait list condition N(%)
Smoker	No	107 (90.7%)	34 (87.2%)	40 (97.6%)	33 (86.8%)
	Yes	11 (9.3%)	5 (12.8%)	1 (2.4%)	5 (13.2%)
Exercise: mild	<Once a week	18 (15.4%)	7 (17.9%)	6 (15%)	5 (13.2%)
	Once a week or more	99 (84.6%)	32 (82.1%)	34 (85%)	33 (86.8%)
Exercise: moderate	<Once a week	86 (72.9%)	30 (76.9%)	28 (68.3%)	28 (73.7%)
	Once a week or more	32 (27.1%)	9 (23.1%)	13 (31.7%)	10 (26.3%)
Exercise: vigorous	<Once a week	94 (81%)	32 (82.1%)	34 (87.2%)	28 (73.7%)
	Once a week or more	22 (19%)	7 (17.9%)	5 (12.8%)	10 (26.3%)
Alcohol drinker	No	20 (16.9%)	4 (10.3%)	10 (24.4%)	6 (15.8%)
	Yes	98 (83.1%)	35 (89.7%)	31 (75.6%)	32 (84.2%)
		Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
	Alcohol use (drinks per 14 days)	10.7 (8.93)	10.8 (8.38)	8.68 (7.11)	12.6 (10.7)

9.3.2 Psychological questionnaire and daily affect and stress measures

Table 9.5 shows the mean (SD) pre-intervention psychological and wellbeing scores from the questionnaire and the daily affect and stress measures by condition. The reliabilities of the psychological questionnaires were acceptable to high, with Cronbach's alpha coefficients ranging from 0.66 to 0.88. Correlations between the psychological questionnaire measures can be seen in Table 9.6. All measures were significantly correlated with each other. The strength of the correlations ranged from weak to moderate with the strongest association between positive and negative affect (r = -.658); this does not suggest the presence of multicollinearity (Field, 2009; Hutcheson & Sofroniou, 1999). There were no significant between-group differences in baseline scores for any of the measures (p values ranged from p= .271 to .946).

Table 9.5: Mean (SD) pre-intervention psychological and wellbeing variables by condition

		Condition: Mean (SD)		
Variable type	**Variable**	**Gratitude (N=40)**	**Daily events (N=41)**	**Wait list (N=38)**
Affect	**Positive affect**	3.41 (0.67)	3.25 (0.68)	3.39 (0.62)
	Negative affect	2.40 (0.59)	2.42 (0.72)	2.50 (0.66)
Positive wellbeing	**Gratitude**	33.7 (4.87)	33.9 (4.78)	34.9 (4.84)
	Optimism	15.5 (5.68)	14.6 (5.04)	14.0 (4.64)
	Life satisfaction	23.2 (6.25)	21.5 (6.57)	22.9 (6.64)
	Flourishing	42.2 (7.76)	41.9 (8.23)	43.6 (5.62)
Mental & physical health	**Depression**	4.65 (3.00)	4.80 (3.03)	3.79 (2.86)
	Anxiety	8.78 (3.92)	8.76 (3.30)	9.11 (3.56)
	Stress	18.3 (5.64)	19.4 (6.14)	19.5 (6.01)
	Self-rated health	3.40 (0.98)	3.34 (1.15)	3.32 (1.00)
Daily measures	**Positive emotional style**	1.93 (0.62)	1.89 (0.58)	1.99 (0.61)
	Negative emotional style	0.68 (0.46)	0.70 (0.47)	0.59 (0.43)
	Daily stress	1.63 (0.45)	1.60 (0.43)	1.58 (0.39)

Table 9.6: Pearson's r correlations between the psychological questionnaire measures

Variable	2	3	4	5	6	7	8	9
1. Positive affect	-.658***	.472***	.528***	.542***	.538***	-.527***	-.576***	-.641***
2. Negative affect	-	-.282**	-.464***	-.414***	-.351***	.372***	.613***	.618***
3. Gratitude	-	-	.441***	.485***	.517***	-.366***	-.312***	-.435***
4. Optimism	-	-	-	.585***	.556***	-.483***	-.534***	-.612***
5. Life satisfaction	-	-	-	-	.616***	-.556***	-.508***	-.578***
6. Flourishing	-	-	-	-	-	-.467***	-.386***	-.525***
7. Depression	-	-	-	-	-	-	.492***	.638***
8. Anxiety	-	-	-	-	-	-	-	.613***
9. Stress	-	-	-	-	-	-	-	-

**p<.01, ***p≤.001

The positive wellbeing baseline means (in Table 9.5) were comparable to values reported in other healthy populations, however the means for the mental health variables were slightly higher than normative values. For example, the mean gratitude scores (33.7 to 34.9) were within the range of normative means listed by McCullough (2015) and similar to a mean GQ-6 score for British college students of 35.1 (Wood, Maltby, Gillett, Linley, & Joseph, 2008). Likewise, the current means were similar to normative values in healthy participants for optimism (Glaesmer et al., 2012), life satisfaction (Pavot & Diener, 1993), flourishing and positive affect (Diener, et al., 2010). The mean baseline HADS depression scores (3.79 to 4.80) were slightly higher than norms from a non-clinical population with a reported mean of 3.68, but were not considered indicative of possible clinical depression (Crawford, Henry, Crombie, & Taylor, 2001). However the mean pre-intervention HADS anxiety scores (8.76 to 9.11) were greater than 8 which indicates the possibility of mild clinical anxiety according to Bjelland, Dahl, Haug and Neckelmann (2002) and Snaith and Zigmond (1994). The perceived stress scores (18.3 to 19.5) were also slightly higher than the normative mean of 16.1 for American women in 2009 (Cohen & Janicki-Deverts, 2012).

The difference scores (post-intervention minus pre-intervention scores) are shown in Table 9.7 along with the results of one way ANCOVAs adjusted for age and baseline score. The overall between groups difference for depression was significant: F(2, 110)= 5.82, p= .004, η_p^2= .096. According to unadjusted *post hoc* comparisons, mean depression difference scores were lower in the gratitude group (-1.36 ±2.64) compared with the daily events (.154 ±2.87, p= .009, d= -.549) and wait list condition (.730 ±2.28, p=.002, d= -.847). The *post hoc* comparisons were still significant according to Bonferroni correction (p= .028, gratitude compared with daily events; p= .006, gratitude compared with wait list). The effect sizes were moderate to large.

Table 9.7: Mean difference scores and ANCOVA results for psychological questionnaire measures and daily affect and stress

		Condition Mean (SD) difference score			ANCOVA results (adjusted for age & baseline score)		
Variable type	**Variable**	**Gratitude (N=39)**	**Daily events (N=39)**	**Wait list (N=37)**	**F**	**p**	**Partial η^2**
Affect	**Positive affect**	.106 (.607)	.226 (.774)	-.060 (.626)	F(2,108)= 1.75	.178	.031
	Negative affect	-.123 (.569)	-.124 (.645)	.069 (.718)	F(2,108)= 2.54	.083	.045
Positive wellbeing	**Gratitude**	1.08 (4.79)	.421 (3.24)	-.972 (4.99)	F(2,107)= 1.65	.197	.030
	Optimism	1.76 (2.31)[ab]	.590 (2.73)	.568 (2.99)	F(2,109)= 3.06	.051[†]	.053
	Life satisfaction	1.89 (4.14)	1.82 (4.04)	.561 (3.14)	F(2,110)= 1.87	.159	.033
	Flourishing	1.74 (4.92)	1.54 (5.44)	-.133 (3.83)	F(2,110)= 1.85	.163	.032
Mental & physical health	**Depression**	-1.36 (2.64)[ab]	.154 (2.87)	.730 (2.28)	F(2,110)= 5.82	.004**	.096
	Anxiety	-.590 (3.17)	.026 (3.09)	.189 (2.88)	F(2,110)= .990	.375	.018
	Stress	-1.72 (5.16)	.079 (5.97)	.111 (3.45)	F(2,108)= 2.19	.117	.039
	Self-rated health	.051 (.916)	-.205 (1.30)	.056 (1.22)	F(2,109)= 1.16	.316	.021
Daily measures	**Positive emotional style**	.064 (.400)[b]	.061 (.530)[b]	-.152 (.511)	F(2,110)= 3.01	.053[†]	.052
	Negative emotional style	.075 (.645)	.003 (.477)	.198 (.658)	F(2,110)= .628	.536	.011
	Daily stress	.026 (.457)	-.014 (.336)	-.065 (.441)	F(2,110)= 1.02	.365	.018

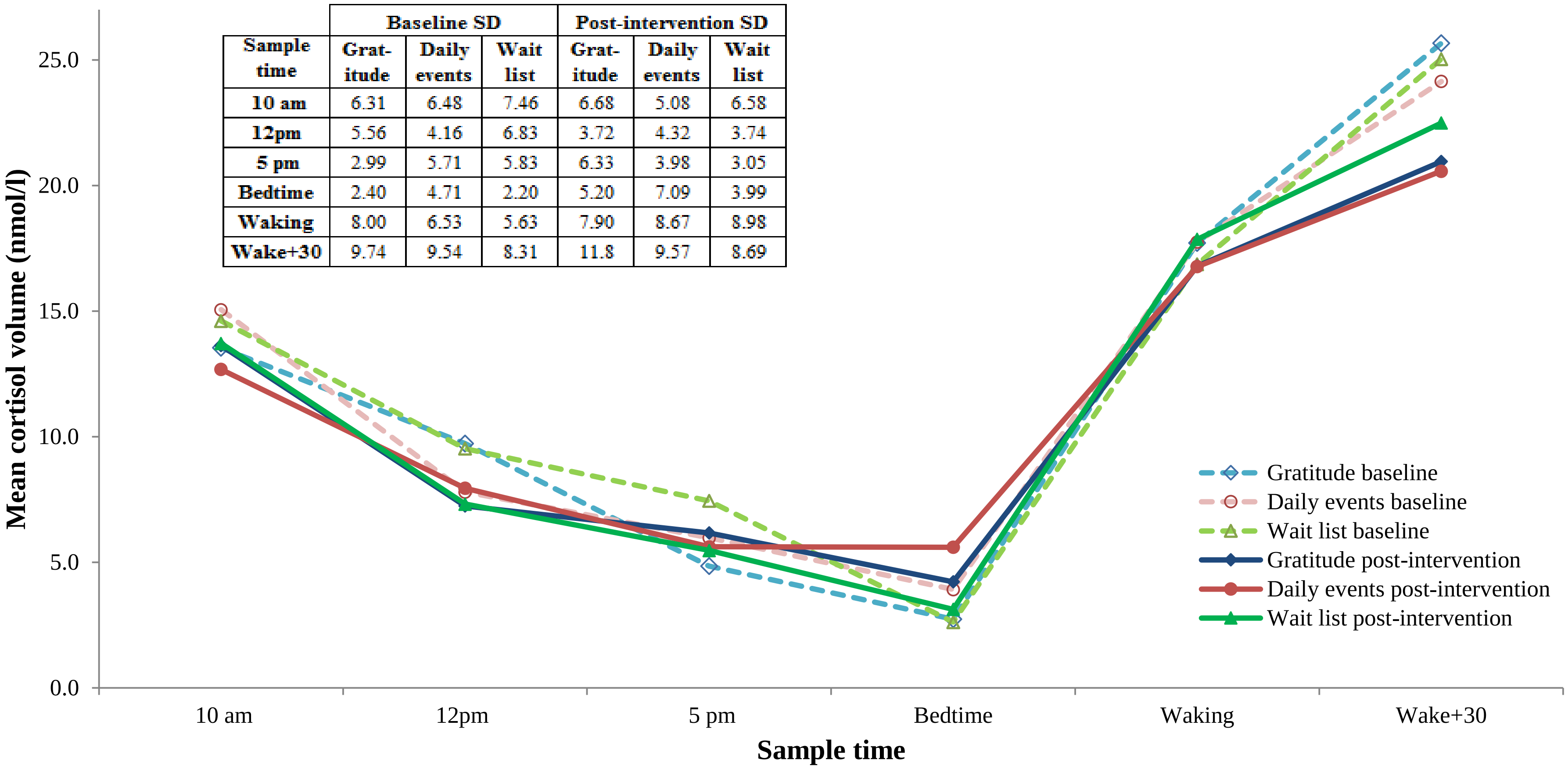
Key: [a] different from daily events condition, [b] different from wait list condition, [†] marginally significant, **p< .01

The ANCOVA results were marginally significant for optimism (F(2,109)= 3.06, p= .051, η_p^2= .053) and daily positive emotional style (F(2,110)= 3.01, p= .053. η_p^2= .052). The mean optimism difference score in the gratitude group (1.76 ±2.31) was significantly greater than both the daily events condition (.590 ±2.73, p= .043, d= .463) and wait list condition (.568 ±2.99, p= .028, d= .446). For daily positive emotional style (PES), the mean difference score for the gratitude group (.064 ±.400) was significantly different from the wait list group (-.152 ±.511, p= .037, d= 0.417) but not the daily events group (.061 ±.530, p= .964). Also, the daily PES difference score in the daily events condition was significantly different from no treatment (p= .033). However, the *post hoc* comparisons for both optimism and daily PES were no longer significant according to Bonferroni correction. The effect sizes were small for both optimism and daily PES.

There were no significant between group findings for any of the other psychological and wellbeing questionnaire measures and daily measures.

9.3.3 Cortisol

Mean cortisol concentrations (nmol/l) across the pre- and post-task monitoring days by condition are shown in Figure 9.8 (standard deviations are shown separately in a table for clarity). The cortisol profiles were typical for healthy adults (the peak value was at 30 minutes after waking and cortisol declined from morning to evening). Bonferroni corrected ANOVAs for the 12pm, 5pm, bedtime and waking+30 samples showed a main effect of time for the waking+30 sample only (F(1, 214)= 9.73, p= .002). The mean waking time pre-intervention was 7.52am (±77 minutes) and post-intervention was 8.13am (±90 minutes).



Sample time	Baseline SD			Post-intervention SD		
	Grat-itude	Daily events	Wait list	Grat-itude	Daily events	Wait list
10 am	6.31	6.48	7.46	6.68	5.08	6.58
12pm	5.56	4.16	6.83	3.72	4.32	3.74
5 pm	2.99	5.71	5.83	6.33	3.98	3.05
Bedtime	2.40	4.71	2.20	5.20	7.09	3.99
Waking	8.00	6.53	5.63	7.90	8.67	8.98
Wake+30	9.74	9.54	8.31	11.8	9.57	8.69

Figure 9.8: Mean (SD in table) cortisol concentrations across the baseline and post-intervention monitoring days by condition

According to Bonferroni corrected t-tests, there were no significant differences in cortisol concentration (across all participants) according to pre-sample smoking, brushing teeth, taking medication, exercise, eating a meal, alcohol or caffeine consumption. Only the post-intervention 10am cortisol sample differed by menstrual phase ($F(5, 105) = 4.44$, $p \leq .001$). For this sample, mean cortisol concentrations for women taking contraceptive medication were greater than women who were in the luteal or follicular stages of the menstrual cycle (contraceptive: 16.2±6.10 nmol/l, luteal: 11.6±5.82 nmol/l, follicular: 10.5±4.60 nmol/l, missing/other: 12.7±6.09 nmol/l). A series of Bonferroni corrected t-tests comparing the use of contraceptive medication versus none, also showed similar results. The only significant difference in cortisol was for the post-task 10am sample ($t= 4.63$, $p\leq .001$). Again, women using contraceptive medication had higher cortisol (N= 48, cortisol: 16.2 ±6.10 nmol/l), compared to those who didn't use contraceptive medication (N= 63, cortisol: 11.2 ±5.23 nmol/l). Because the pre-sample conditions, menstrual phase and use of contraceptives were not consistently related to the cortisol samples, the ANCOVA models were adjusted for the planned covariates only (age, BMI, waking time and baseline values).

Mean baseline and difference scores for cortisol awakening response (CAR), logged values of total cortisol as area under the curve (AUC) and cortisol slope are shown in Table 9.9. There were no differences in baseline cortisol measures between groups (p values ranged .451 to .897). All cortisol measures decreased from pre to post-intervention in all 3 conditions as seen in the mean difference scores (Table 9.9). There were no significant between condition differences for any of the cortisol variables as seen in the corresponding ANCOVAs in Table 9.9.

Table 9.9: Mean (SD) baseline and difference scores for cortisol awakening response (CAR), total cortisol and cortisol slope by condition with ANCOVA results for the difference scores (adjusted for age, BMI, waking time and baseline score)

		Condition Baseline mean (SD)			Condition Mean (SD) difference score			Difference score ANCOVAs (adjusted for age, BMI, wake time & baseline score)		
Variable	**Value**	**Gratitude**	**Daily events**	**Wait list**	**Gratitude**	**Daily events**	**Wait list**	**F**	**p**	**Partial η^2**
CAR (nmol/l)	**N**	36	34	35	26	25	28			
	Mean (SD)	8.40 (8.99)	7.00 (12.9)	8.50 (8.27)	-1.80 (12.7)	-3.46 (13.3)	-3.19 (11.0)	F(2,72) = .139	.871	.004
Total cortisol (AUC_G, log)	**N**	39	39	37	34	34	34			
	Mean (SD)	9.50 (.312)	9.53 (.341)	9.59 (.335)	-.054 (.397)	-.060 (.393)	-.169 (.343)	F(2,95) = .465	.630	.010
Cortisol slope (nmol/l/min)	**N**	40	38	37	36	32	34			
	Mean (SD)	.019 (.007)	.019 (.008)	.019 (.006)	-.002 (.010)	-.005 (.009)	-.002 (.008)	F(2,95) = 1.54	.220	.031

9.3.4 Blood pressure and heart rate

Mean baseline blood pressure and heart rate (see Table 9.10) did not differ across the three conditions (p values ranged .122 to .925). The results of one way ANCOVAs for difference score (adjusted for age, BMI and baseline values) were not significant for any of the blood pressure and heart rate variables (see Table 9.10). The mean difference score for diastolic blood pressure in the gratitude group showed a decrease from pre to post-intervention (-1.95 ±4.90) and was significantly different than the wait list group which showed a slight increase (.293 ±4.65, p= .041, d= -0.470). This finding had a small effect size, but was no longer significant according to Bonferroni correction. There were no other between group differences for blood pressure and heart rate.

Table 9.10: Mean (SD) blood pressure and heart rate baseline and difference scores by condition with ANCOVA results for the difference scores (adjusted for age, BMI and baseline score)

	Condition Baseline mean (SD)			Condition Mean (SD) difference score			Difference score ANCOVAs (adjusted for age, BMI & baseline score)		
Variable	**Gratitude (N=39)**	**Daily events (N=41)**	**Wait list (N=37)**	**Gratitude (N=37)**	**Daily events (N=38)**	**Wait list (N=35)**	**F**	**p**	**Partial η^2**
Systolic blood pressure (mmHg)	113 (8.55)	112 (7.19)	116 (7.30)	-1.76 (5.83)	-1.33 (6.08)	-1.26 (6.32)	F(2,104)= .866	.424	.016
Diastolic blood pressure (mmHg)[†]	74.2 (6.02)	73.7 (6.68)	73.7 (5.96)	-1.95[b] (4.90)	-.339 (4.87)	.293 (4.65)	F(2, 102)= 2.23	.113	.042
Heart rate (BPM)	77.7 (8.81)	76.0 (7.13)	75.6 (9.29)	-1.02 (8.68)	.195 (7.58)	1.80 (8.57)	F(2, 104)= .653	.522	.012

Key: [†] Baseline: N= 40 for daily events, N= 36 for wait list, difference score: N= 36 for gratitude, N= 34 for wait list

[b] different from wait list condition

9.3.5 Writing task compliance

According to the self-reported measures of completion and effort, the majority of the participants indicated they had completed all of the writing exercises (6 in total) and had put in quite a lot of effort (see Table 9.11). There were no significant differences between the groups for completion ($\chi^2(1)= .333$, p= .620) and effort ($\chi^2(2)= .339$, p= .884).

Table 9.11: Self-reported ratings of writing task compliance

Self reported ratings		Condition: Gratitude N (%)	Condition: Daily events N (%)
Completion	**<6 times (out of 6)**	10 (25.6%)	12 (31.6%)
	6 times (out of 6)	29 (74.4%)	26 (68.4%)
Effort	**Very little effort**	4 (10.3%)	5 (13.2%)
	Quite a bit of effort	29 (74.3%)	26 (68.4%)
	A lot of effort	6 (15.4%)	7 (18.4%)

9.3.6 Day typicality

The participants indicated that the majority of days during the monitoring weeks were typical (see Table 9.12). Around 60% of the days that had been rated were typical, approximately 16-20% were atypical where bad/stressful things happened and approximately 16-25% of the days were atypical where good things happened. These percentages were similar for all conditions during pre- and post-task monitoring weeks and were not significantly different according to ANOVAs (p values ranged from .303 to .932).

Table 9.12: Percentage of monitoring days rated typical or atypical by condition

	Mean (SD) percent of day typicality ratings					
	Pre-intervention			Post-intervention		
Day type	**Gratitude**	**Everyday**	**Wait list**	**Gratitude**	**Everyday**	**Wait list**
Typical	59.2 (27.1)	58.6 (29.1)	63.6 (22.9)	58.1 (30.0)	61.0 (25.0)	65.2 (25.6)
Atypical: bad	17.6 (18.0)	20.3 (20.5)	16.0 (13.8)	17.1 (18.2)	16.9 (14.6)	19.2 (23.8)
Atypical: good	23.2 (20.8)	21.1 (16.9)	20.5 (18.2)	24.8 (25.1)	22.1 (20.5)	15.6 (15.9)

9.4 Discussion

The Wellbeing Study aimed to examine causal pathways between changes in positive wellbeing and changes in health related biological correlates. The results suggest that the gratitude intervention had little effect on improving positive wellbeing and even less of an impact on biology. There was an increase in optimism and a decrease in depression from pre- to post-intervention in the gratitude condition compared with daily events and no treatment, with small to moderate effect sizes. There was also an increase in daily positive affect in the gratitude condition compared with no treatment, and in the active control (daily events) compared with no treatment. Diastolic blood pressure decreased by almost 2mmHg from baseline to post-intervention in the gratitude condition and this change was also different from no treatment. However, after Bonferroni correction, the only significant result was for the change in depression. The results for the other psychological and biological variables were not significant.

Overall, the results provide limited support for the first hypothesis, as there were only a few improvements in positive wellbeing and mental health in the gratitude group. The decrease in depression scores was consistent with previous gratitude interventions, which have also demonstrated improvements to mental health (Emmons & McCullough, 2003; Froh, et al., 2009; Froh, Sefick, & Emmons, 2008; Lyubomirsky, et al., 2011). Although the findings were not significant in the adjusted analyses, the increase in optimism and daily positive affect was similar to previous studies reporting improvements to positive wellbeing following gratitude tasks (Emmons & McCullough, 2003; Froh, et al., 2009; Froh, et al., 2008; Watkins, Woodward, Stone, & Kolts, 2003). However, daily positive affect also improved in the daily events condition relative to no treatment which suggests the change was not specific to the gratitude task. We did not see any significant changes in the questionnaire measures of affect. This was surprising considering the significant results for depression which is closely linked to negative affect.

The significant results for depression were important as we intended to select participants with some emotional distress. It is interesting that depressed mood rather than anxiety was reduced in the gratitude group, considering that the participants had higher pre-intervention anxiety scores compared with depression. The improvement in depressive symptoms in the gratitude group suggests that this intervention can be beneficial to mental health even in a short time period. However, whether these effects are long lasting remains to be determined. Aside from depression, there were no other significant results for self-reported mental and physical health.

Although gratitude appeared to increase to a slightly larger extent in the gratitude task compared to the daily events task, the difference was not significant. As noted in the introduction, gratitude interventions may not necessarily be driven by changes in gratitude (Wood, et al., 2010). The results of the current study provide further evidence towards this notion. Emmons and McCullough (2003) reported that increases in positive affect (but not decreases in negative affect) were mediated by changes in daily gratitude, so perhaps gratitude influences intervention outcomes via indirect effects. In this study, it appears that the main effects of the gratitude intervention were improvements to optimism and depressive symptoms, rather than improvements to gratitude.

For the biological variables, there was a reduction in diastolic blood pressure in the gratitude task condition. This finding was no longer significant in the adjusted analyses but the direction of change is consistent with studies reporting reduced blood pressure following meditation based interventions (see Goldstein, et al., 2012). There were no significant findings for systolic blood pressure, heart rate and cortisol. This means there was insufficient evidence to support the second hypothesis (that the biological variables would change to a greater extent in the gratitude condition). Also, change scores for the majority of the psychological variables were not significantly different in the gratitude condition; therefore evidence for demonstrating causal routes here is not apparent. If there is a causal link between improved positive wellbeing and changes to biology, then improvements to wellbeing will probably need to be more robust than in the current study to provide convincing evidence.

The lack of findings for the biological variables may be due to high intra- and inter-individual variability which makes demonstrating significant results difficult (as noted in Chapter 5 for cortisol). In the current study, the cortisol slopes were steeper and the CAR and total cortisol decreased from pre- to post-intervention in all 3 conditions. The reduction in cortisol could be due to order effects: perhaps the unfamiliarity or stress of collecting the cortisol samples across the day was no longer present on the post-intervention monitoring day.

It may be that any effects of post-intervention changes in wellbeing on biology only become apparent several weeks or months after the intervention. The gratitude diary may need to be kept for longer to elicit changes in wellbeing that are strong enough to affect biology. For the current study, we did not want to elongate the procedure any further by including a longer intervention or an additional follow up because the procedure already took 4 weeks to complete and the participant burden was fairly high. However, future studies could modify the design and include the collection of follow up measurements or ask participants to keep a gratitude diary for a longer period.

In general, the procedure and writing tasks were well received and tolerated by the participants (despite the large number of measures). This was seen in the low attrition rates and good task compliance and effort. The use of two comparison conditions including an active control was helpful because effects specific to the gratitude task could be identified. There was some indication that positive wellbeing improved in the daily events control as seen by the increase in daily positive affect. Perhaps writing about everyday events influenced daily positive affect because the task included instructions to '*…become more aware of what is happening around you'.* Conceptually, this may overlap slightly with mindfulness which involves an increased awareness of the present (including one's surroundings). However, it could just be a placebo effect because the instructions were matched to suggest that both the gratitude and daily events tasks could have a positive effect on mood.

Despite the limited findings, the Wellbeing study was an ambitious and novel attempt to demonstrate causation. There are only a few studies examining the effects of gratitude interventions on positive wellbeing and so far none have assessed biology (to my knowledge). The strongest finding suggested that depressed mood in women may be reduced by a relatively short, and easy to complete writing task. This may have clinical applications. For example, because of the suggested association between depression and cardiac health (e.g. Whang et al., 2009), it is possible that interventions designed to increase positive wellbeing and reduce depression may also influence physical health through changes to biological correlates such as blood pressure. There has been very little research into the use of gratitude tasks in clinical settings, so it remains to be determined whether or not this intervention would be useful in promoting wellbeing in this context.

9.4.1 Limitations

The main limitation to the study design is that we used a low intensity intervention over a relatively short time. This may have been too short to elicit physiological changes, as noted in the discussion. However, we may have risked higher attrition if the intervention task duration was increased. Further suggestions for improvement to the intervention task and design limitations are discussed in Chapter 10 (section 10.3).

As in the Daytracker study, it would have been advantageous to have a greater number of monitoring days for the cortisol and blood pressure measures. Perhaps the measures from a single monitoring day were not substantial enough to generate reliable data. Some participants had missing biological data; in these cases monitoring across 2 days may have been useful. Also, several participants reported removing the blood pressure cuffs due to discomfort or inconvenience e.g. during meetings or vigorous activity. Future studies may wish to consider using ambulatory blood pressure monitors worn around the wrist (although this would involve substantial costs).

The study sample was quite highly selected because of the specific inclusion criteria. Additionally, because the participants were recruited from universities and the majority was postgraduate students, the level of education is higher than in the general population. However, a more homogenous sample was also advantageous in this study because it included measurements with large individual differences (e.g. cortisol). Future studies may not necessarily need to be so selective, and therefore may be able to recruit participants from the general population.

9.4.2 Conclusion

The results suggest that the gratitude task evoked very limited improvement in positive wellbeing and biology. Therefore, robust evidence for causal pathways between changes in wellbeing and changes in biology cannot be provided. Despite the lack of significant results, the findings are moderately promising since they suggest improvements in mental wellbeing and reductions in blood pressure could be possible in a relatively short time frame with a simple writing task. The current study adds to the literature by including objective measures of health related biological correlates, measures of both daily and global affect, and a range of psychological variables which have not yet been investigated as part of a gratitude intervention. Future studies could focus on improving the efficacy of the intervention task.

10 General discussion

10.1 Overview of the thesis findings: is positive wellbeing health protective via biological mechanisms?

Chapter 1 identified a number of problems in the field of positive wellbeing and biological correlates of health. Studies were heterogeneous, employing various measures of positive wellbeing and biological correlates, as well as utilising different methodologies in a range of participant samples. Therefore, it was difficult to get an overview of the positive wellbeing and biology links. Another problem was the lack of evidence for causal mechanisms explaining the link between positive wellbeing and health. The studies presented in this thesis aimed to overcome some of these difficulties.

Chapters 4 to 6 assessed relationships between resilience as an example of a positive personality trait and a number of biological and psychological factors. By focussing on one particular positive trait relevant to both stress and health, within a relatively homogeneous sample of women, I aimed to clarify potential resilience and biology links. Previous studies examining resilience and objective health-relevant measures were scarce and the role of resilience in attenuating the chronic stress and wellbeing relationship was not extensively tested.

The results suggested that higher resilience was associated with increased high frequency heart rate variability (HF-HRV) and reduced LF/HF ratio during the working day but not the leisure day (Chapter 6). Additionally, Chapter 4 provided evidence that resilience partially mediated the relationship between chronic stressors and affect/wellbeing outcomes. Moreover, there was no significant relationship between resilience and cortisol (Chapter 5). A discussion of the results from the resilience studies was presented in Chapter 7. The main conclusion here was that resilience in women may be most relevant to biological correlates of cardiac health, as seen by the significant associations with HRV.

The results of the gratitude intervention study were presented in Chapter 9. This study aimed to see if it was possible to increase positive wellbeing within a relatively short amount of time, and if so, to assess whether this caused changes in health-related biological correlates. Changes in biology following a short, self-administered intervention such as the gratitude task had not previously been tested. The results of the intervention were limited: optimism increased and depressive symptoms and diastolic blood pressure decreased in the gratitude group compared with the daily events group and no treatment. Apart from depressive symptoms, these findings were not particularly strong. Considering the lack of significant findings, evidence for causal mechanisms cannot be provided at this point. The intervention task and/or study design may need to be altered to elicit stronger increases in positive wellbeing before making inferences about causation.

The lack of significant findings for cortisol was consistent throughout the studies in the thesis. It seems that effects are more evident in cardiovascular measures. The connection between cognitive processes and the sympathetic/parasympathetic nervous control of the heart is very direct. Links between cognition and the cortisol response are less direct and are complicated by many confounding factors at each stage of the HPA axis (Andreassi, 2007). This may explain why it was difficult to demonstrate significant results for cortisol. The issue of high intra- and inter-individual variability in cortisol was discussed in Chapter 5. Alternatively, it could be that cortisol is simply not related to resilience and that the intervention study was not strong enough to elicit any changes in cortisol. The lack of previous findings in these areas could indicate that other researchers have also found null results. Both the Daytracker study and the Wellbeing study included at least 6 samples of cortisol across the day and provided calculations of the CAR, cortisol slope and total output. Therefore, the lack of significant findings for cortisol was not due to using one particular measure over another. However it might be helpful in future to have a greater number of monitoring days.

The overall aim of this thesis was to provide evidence for the notion that positive wellbeing provides health protective benefits via psychobiological mechanisms. The association between HRV and resilience is a novel finding which may go some way to help explain the link between positive wellbeing and cardiovascular health. Although the adjusted comparisons were not significant, the decrease in diastolic blood pressure following the gratitude task in the Wellbeing study was promising considering the intervention was relatively brief and simple. Overall there is modest evidence that positive wellbeing is associated with healthy indicators of cardiovascular function. However, until the causal mechanisms behind this can be established it is not possible to say that positive wellbeing is health protective via psychobiological routes. Suggestions to help improve the studies presented in this thesis are set out in the next sections, including specific issues related to the Wellbeing Study. It may be possible in the future to provide stronger evidence for psychobiological mechanisms with some modification to experimental design.

10.2 General limitations and future directions for the studies in this thesis

Specific limitations have been given at the end of each study chapter and in Chapter 7 (for the resilience studies). However, there are a number of general limitations which are common to the studies in this thesis. The participants in both the Daytracker study and the Wellbeing Study had similar characteristics. They were all women, the majority was highly educated, without children and fairly young. Having a homogenous participant sample was advantageous in both cases as it allowed the number of potential confounding factors to be reduced. However, the results of the studies are also limited to very specific groups and may not generalise to the wider population.

The resilience studies were cross-sectional and the Wellbeing Study assessed short term changes in positive wellbeing. Therefore, it was not possible to examine changes to biology over longer time spans e.g. months or years, which may be more relevant to the development of health problems. Even if we had found evidence for causal mechanisms in the Wellbeing Study, this would only be relevant to the positive wellbeing and biology link. Further studies are necessary to assess changes in health status over time to fully understand links between positive wellbeing and health.

Therefore, the next steps for the Daytracker study and the Wellbeing Study will be to repeat the studies in men and with participants randomly selected from the general public. This will enable us to make wider generalisations. Additionally, long term changes in biology and psychology could be assessed. As discussed in Chapter 2, resilience is often regarded as a relatively enduring characteristic, but one that is amenable to change following experience. Therefore, follow up studies for the Daytracker study would be suitable every few years to allow possible changes in resilience to occur. The Wellbeing Study could be followed up at one month post-intervention and possibly up to 6 months (as in Seligman, et al., 2005). This would enable us to assess the longevity of any changes to positive wellbeing and biology following the gratitude intervention. However, before we can do this, it would be important to improve the efficacy of the intervention to induce stronger changes in positive wellbeing.

Finally, the studies in this thesis have treated positive wellbeing as a potential protective factor for future health outcomes. It has been noted previously that the relationship between positive wellbeing and health could be the other way around or even bidirectional. Therefore, future experiments would be needed to assess whether changes in biology cause changes to wellbeing.

10.3 Improving intervention efficacy

10.3.1 Design factors

As noted in Chapter 8, the frequency and duration of the tasks is an important factor in determining intervention efficacy. Longer interventions tend to be more effective, but the dose-response relationship is currently unclear (Sin & Lyubomirsky, 2009). Only a few interventions have been tested at different levels of frequency and duration, such as the gratitude task. Emmons and McCullough (2003) found that keeping daily gratitude lists for 2 or 3 weeks was sufficient to elicit increases in positive affect, but there were no significant increases with 10 weeks duration. Perhaps if we had used a different dose for the gratitude task we might have improved the strength of the results. However, the duration and frequency of the gratitude task in the Wellbeing study was chosen in order to avoid attrition because there was already a high participant burden from including biological assessment. Also, increasing the duration might not necessarily improve the intervention due to 'hedonic adaptation'.

The concept of hedonic adaptation suggests that people become used to the changes in affect associated with either positive or negative events, so that the intensity of affective responses is reduced (Frederick & Loewenstein, 1999). Put in the context of positive interventions, the increases in positive wellbeing initially induced by intervention tasks may reduce over time, so that the same task may no longer have the desired effect (Lyubomirsky, et al., 2005b). Long interventions may therefore benefit from methods designed to reduce hedonic adaptation such as using more than one task. In future, perhaps the gratitude task and another positive psychology intervention task could be used concurrently or consecutively to strengthen the impact of the intervention.

Including social factors as part of positive wellbeing interventions may help increase their effects, although the level and type of social interaction is important here. For example, administering the BPS writing task online, compared with in person, did not seem to differ in terms of intervention efficacy (Layous, Katherine Nelson, & Lyubomirsky, 2013a). However, interventions conducted in groups rather than individually may provide some additional benefits such as encouragement from intervention group leaders and social support. Indeed, even peer-led mutual help groups (without the guidance of a therapist or professional group leader) may be effective for treating emotional problems such as depression, although the evidence here is limited (Pistrang, Barker, & Humphreys, 2008).

10.3.2 Replicability of results

Emmons and McCullough's (2003) original US-based gratitude study has been successfully replicated in a Spanish sample with broadly similar results (Martinez-Marti, et al., 2010), however replications of other interventions have been rather mixed. For example, Seligman et al's (2005) seminal paper presenting several different interventions has been widely cited but attempts at replications have been limited. Mongrain and Anselmo-Matthews (2012) replicated the strengths and '3 good things' tasks from the original study. They reported that although happiness increased following both tasks and persisted for up to 6 months, contrary to Seligman et al's findings, depression scores were not significantly reduced. Also, the strengths and '3 good things' tasks did not differ from a positive placebo task. An unpublished replication by Brosschot and colleagues at Leiden University found that the '3 good things' task did not induce increases in happiness and was not associated with changes in self-reported health (Brosschot, Van der Togt, & Verkuil, 2012).

A possible reason for the differences in findings could be due to the ‘file drawer’ problem and publication bias towards positive results i.e. there may be other null findings which have either not been reported or did not get published. Alternatively, differences may be attributed to participant factors such as motivation and cultural differences. For example, Seligman et al and Mongrain and Anselmo-Matthews conducted their studies in North America (USA and Canada respectively) and recruited participants with an interest in improving happiness, whereas Brosschot et al’s study involved a convenience sample of Dutch participants. It would be interesting to replicate the Wellbeing study using a different population as the results may vary.

10.3.3 Participant factors

A number of different demographic and psychological factors have been suggested to affect positive wellbeing intervention response, such as age, gender, and baseline wellbeing. Sin and Lyubomirsky (2009) reported that older participants generally responded better than younger participants to positive wellbeing interventions, as seen by larger increases in positive wellbeing. Gender differences may also play a role in intervention response. For example, it has been suggested that men may respond differently to gratitude tasks, based on the argument that the expression of gratitude in men may provoke feelings of dependence or a sense of debt (McCullough, et al., 2002). There is, however, very little evidence so far to support this claim. The small participant numbers in most gratitude studies may have made any gender differences difficult to detect.

The influence of individual differences in baseline mood and symptoms of depression on intervention response are perhaps more apparent. Participants with lower levels of baseline positive affect and with higher levels of depression show greater increases in positive wellbeing following intervention (Froh, et al., 2009; Sin & Lyubomirsky, 2009). Seligman et al (2006) suggest that positive wellbeing interventions may be better suited to people with greater symptoms of depression or even major depressive disorder (MDD), compared to people with mild to moderate depression. However, they caution that positive wellbeing tasks should be used alongside more traditional treatments and that the timing may be important, suggesting that positive tasks may be particularly useful for maintaining recovery from major depression or preventing recurrence. Again, it is unclear here whether people with severe depression benefit more than people with milder symptoms due to floor effects (i.e. people with greater symptoms of depression have more scope to improve).

The participants in the Wellbeing study were selected to have some symptoms of mental distress and mean HADS scores were indicative of mild anxiety but not mild depression. Additionally, there were no differences in baseline measures of depression or positive wellbeing across the 3 conditions. To improve intervention efficacy we could select participants with MDD. However, this would make assessing changes in biology problematic since depression has been linked to cortisol dysregulation (Gillespie & Nemeroff, 2005). There are also ethical considerations in recruiting participants with mental illness since the intervention may be interpreted as a treatment.

Overall, the participants in the Wellbeing study were all healthy, young women with similar baseline mental wellbeing. Therefore individual differences in participant characteristics were unlikely to have influenced the efficacy of the gratitude task. The weak effect of the gratitude intervention may be task related. Either the dose was not correct or the effect size of the intervention was too small to elicit significant changes in positive wellbeing.

10.3.4 Effect size

The small to moderate effect sizes in the Wellbeing study were comparable to effect sizes in other positive psychology based interventions (Sin & Lyubomirsky, 2009). Small effect sizes are not necessarily a problem in themselves. If an intervention can be administered to a large number of people at a low cost and with no harmful effects, then it may still provide some benefit. Indeed the effect sizes of some very important treatments are also very small e.g. an effect size estimate for aspirin in preventing heart attacks was put at r= 0.03 (Rosenthal & Rasnow, 2008). Several positive wellbeing interventions would be suitable for large scale studies as they can be self-administered and based online, although cost-benefit analyses have yet to be performed. However, a large study would have been prohibitively expensive for the Wellbeing study because we also wanted to assess changes in biology.

10.4 General issues in positive wellbeing research

10.4.1 Measurement issues

Chapter 1 suggested that one of the reasons for the inconsistency of findings in the positive wellbeing and health field could be differences in the measurement of positive states or traits. Because of the paucity of research in this area, it remains unclear as to whether the various measures of positive wellbeing are assessing different aspects of emotional and cognitive processes, and whether the different wellbeing measures have distinct biological correlates. Although the broad categories of hedonic and eudaimonic wellbeing have been defined, it may be necessary to further divide aspects of wellbeing within each sub-category. For example, the affective elements of hedonic wellbeing (positive and negative affect) are quite different from the cognitive aspect of life satisfaction. Most trait measures of positive affect require participants to assess how often they have experienced various mood states over a particular period of time (as in the PANAS) whereas measures of life satisfaction include broad, global evaluations, such as agreeing or disagreeing with the statement “In most ways my life is close to my ideal” from the Satisfaction with Life Scale (Diener, et al., 1985).

A further complication comes from whether a measurement of positive wellbeing is assessing a state or trait. As seen in the examples of associations between positive wellbeing and biological correlates in Chapter 1, quite different findings can be demonstrated depending on whether researchers are assessing state or trait measures of positive affect. For example, blood pressure has been reported to be higher during periods of laboratory-induced positive affect and when measured concurrently to naturally occurring episodes of positive affect in some ambulatory studies (e.g. Gellman, et al., 1990; Neumann & Waldstein, 2001; Shapiro, et al., 1997). However, higher trait measures of positive wellbeing have been associated with lower blood pressure (Ostir, et al., 2006; Räikkönen, et al., 1999). Perhaps the cumulative effects of regular positive affective states have a different influence on biology than that observed during single episodes. Future ambulatory studies may need to focus on particular aspects of emotional wellbeing such as frequency of positive and negative affect and level of arousal.

10.4.2 Is positive wellbeing necessarily ‘good’?

The stance of this thesis has generally considered that greater levels of positive states and traits may be beneficial to health and wellbeing. However, there is some evidence that positive wellbeing could have the opposite effect in certain circumstances.

For example, very high levels of positive affect have been associated with reduced lung function in adults with mild to moderate asthma (Ritz & Steptoe, 2000) and have even triggered asthma attacks in children (Liangas, Morton, & Henry, 2003). Level of cheerfulness (optimism and sense of humour) has also been inversely correlated with longevity (Friedman et al., 1993). Reasons for this inverse association were unclear although it has been theorised that high levels of optimism could result in unrealistic health risk assessment which may consequently affect health outcomes (Gruber, Mauss, & Tamir, 2011).

Related research may go some way to support this idea as it has been suggested that people with very high levels of positive affect may engage in riskier health-related behaviours such as alcohol use and binge eating (Cyders & Smith, 2008), also that people with a positive outlook may under-report their symptoms (Cohen, et al., 2003). It has therefore been suggested that the relationship between positive wellbeing and health may not be linear (Gruber, et al., 2011; Pressman & Cohen, 2005). Very high levels of positive affect may have negative consequences on health. However, it should be noted that the vast majority of significant findings suggest that positive wellbeing may be beneficial for health (see Chapter 1). People who experience frequently occurring, very high levels of positive affect may not be representative of the general population. Indeed extreme levels of positive affect may even indicate underlying psychopathology, as seen in mania (Gruber, 2011).

10.4.3 Positive wellbeing as a 'cure-all'

The notion of improving positive wellbeing as a 'cure-all' solution for a number of psychological and physical health problems has received a lot of recent attention in the media and has been explicitly stated by a number of self-help books claiming to be based on scientific evidence. This has not helped to improve the credibility of research within positive psychology, but has at least highlighted the potential of positive wellbeing research to open up new areas of investigation, particularly in a preventative health context. However, the danger of making generalisations about the effects of positive wellbeing interventions or the strength of positive wellbeing-health links is apparent in the inconsistency of findings and the lack of quality scientific evidence in these areas. It has even led to the perception that people with serious illness 'ought' to have high positive affect, and that if they do not they only have themselves to blame if their condition worsens (Sloan, 2011).

As noted in Chapter 1, the field of positive wellbeing-health links is still a relatively recent area for inquiry, so both the number and quality of studies should increase over time. Until then, it is important to emphasize the limitations to the current research and to realise that it may be too early to promote positive wellbeing interventions as a means to improve health without sufficient scientific evidence.

10.5 Future directions for research in positive wellbeing and biology

Research into the links between positive wellbeing and biology has only recently expanded; therefore there is plenty of scope for future progress. Intervention studies should focus on the development of robust evidence-based methods of improving wellbeing. Frequency and duration of intervention tasks should be adjusted systematically until significant improvements in positive wellbeing can be demonstrated. Also, more than one task could be used to strengthen intervention effects and to reduce hedonic adaptation.

The use of mobile monitoring technology could be used to investigate more effectively the biological correlates of positive wellbeing. For example, heart rate can now be assessed via optical sensors in mobile phones and blood pressure can be monitored using wrist units. The use of smaller and more convenient monitoring equipment may help to reduce study attrition and participant burden. Also, biological monitoring over longer periods of time could become more feasible.

Mobile technology could also be used to aid the investigation of positive states. For example, participants could be sent a text message at various points in the day asking them to rate their mood state and intensity. Participants could indicate the start and end times for periods of positive affect in real time, via a mobile phone application. In this way, it may be possible to explore whether duration and frequency of positive affect is related to health-relevant factors over periods of months or even years.

Additionally, it would be interesting to investigate links between positive wellbeing and time use. It could be that some people are happier because they are engaging in activities that bring pleasure such as socialising or hobbies. Alternatively, more positive people might feel happy regardless of how they spend their time.

Since up to 50% of individual differences in subjective wellbeing can be explained by genetics, perhaps the link between positive wellbeing and health-relevant biological factors may be explained by common genetic factors. This may help to explain possible links between positive wellbeing and cortisol, because cortisol regulation is partly genetically determined.

If we are to gain a better understanding of the links between positive wellbeing and health, then future approaches will need to employ multiple methods and be conducted in the same cohort over several years. Such studies could assess data from a variety of approaches including genetics, biological correlates of health, disease incidence and even mood induction studies using sub-samples of the main dataset.

10.6 Conclusion

The studies presented in this thesis offer a unique perspective on addressing our understanding of links between positive wellbeing and health. Associations between resilience and health-relevant biological and psychological factors were investigated, and an intervention task was used to test causal mechanisms between changes in positive wellbeing and biology. The main findings suggested resilience was associated with increased HRV during the work day but was not associated with cortisol. It was not possible to demonstrate causal mechanisms because the intervention task did not elicit strong changes in positive wellbeing.

The findings will add substantially to current knowledge since the relationship between resilience, HRV and cortisol was previously unclear, as was the role of resilience in attenuating chronic stress and wellbeing relationships. With improvements to positive psychology interventions, it may be possible to make inferences on the presence of causal mechanisms between positive wellbeing and biology. This is an important area for development as there is currently very little evidence for causation. Future research should focus on strengthening the effects of the currently available tasks or perhaps developing new intervention methods. The inclusion of additional measurements such as genetic factors or disease incidence in longitudinal studies could help determine whether positive wellbeing is health protective.

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Appendices

Appendix 1: Saliva diary extract for the Daytracker study

The extract below shows the instructions for taking the samples and one page from the booklet (for the 10am sample):

THE SALIVA SAMPLES.

Your saliva sampling day will be on _______________, the_________ of ______________.

Over the course of tonight and tomorrow you will be collecting saliva samples at 6 different times. Please collect the samples at the times listed below. It may be helpful to set an alarm on your watch or phone to remind you. Each time you collect a sample, please answer the questions in this booklet. There are separate questions (one set per page) for each sample.

You will need to place the tube for the waking sample (Tube 3) and this booklet next to your bed before you go to sleep tonight.

Your honesty is very important to us in analysing the data. Please write down the actual collection time, even if it is different to the designated time, and answer the questions as accurately as possible.

Instructions.

1. Do not eat or drink anything for 15 minutes before you collect the sample.
2. Remove the small plastic cap, and place the cotton swab in your mouth, avoiding touching it with your hands.
3. Gently chew on the swab until it is soaked, this will usually take about 2 minutes. While you are doing this, answer the questions for this sample in this booklet.
4. Once the swab is soaked, place it back in the tube, trying not to use your hands. Put the cap on securely, and place the tube in the plastic bag provided.
5. Store the bagged tube in a cold place or in a refrigerator.

Sample Time	**Tube Number**	**Instructions**
Bedtime	1	
Waking	2	This first sample should be collected as soon as you wake up, and before you get out of bed.
30 minutes after waking	3	Take this sample 30 minutes after your awakening sample. Do not have any caffeinated drinks, brush your teeth or eat before you collect this sample.
10 a.m.	4	
12 p.m	5	
3 p.m.	6	

App. 1 continued

TUBE 5 : AT 10 A.M.

1. ***What is the time now?*** a.m. / p.m.

2. ***What was the exact time you collected the sample?*** a.m. / p.m

3. ***For the next two questions, please use the codes for location and activity that are listed on the last page.***

Where are you? _____________ ***What are you doing?*** _________

In the last 30 minutes how much did you feel…..

		Not at all				*Very much*
4.	In control	**1**	**2**	**3**	**4**	**5**
5.	Tired	**1**	**2**	**3**	**4**	**5**
6.	Happy	**1**	**2**	**3**	**4**	**5**
7.	Frustrated or angry	**1**	**2**	**3**	**4**	**5**
8.	Rushed	**1**	**2**	**3**	**4**	**5**
9.	Stressed	**1**	**2**	**3**	**4**	**5**
10.	Pain	**1**	**2**	**3**	**4**	**5**
11.	If you talked with others, how pleasant was the interaction?					
	Not applicable ○	**1**	**2**	**3**	**4**	**5**

In the last 30 minutes, but before you collected your sample did you….

12.	Brush your teeth	**No**	**Yes**
13.	Drink any tea, coffee or other caffeinated drinks	**No**	**Yes**
14.	Take any medicines	**No**	**Yes**
15.	Eat a meal	**No**	**Yes**
16.	Drink any alcohol	**No**	**Yes**
17.	Do any exercise?	**No**	**Yes**
18.	Smoke any cigarettes?	**No**	**Yes**

Appendix 2: The Daytracker study questionnaire extract

*[**Note:** The original questionnaire (which had 21 sections) has been edited here to only present sections relevant to the studies in Chapters 4 to 6. Comments in square brackets have been added to explain questionnaire structure, to identify the various questionnaires and to indicate information not shown here (as **[...]**). Comments in square brackets were not included in the participant's version. Standardised scales have not been included for brevity; however the order of questionnaire presentation has been indicated by the section headers].*

Daytracker Study Questionnaire

Thank you very much for agreeing to participate in the Daytracker Study, a research study that is examining how health and wellbeing are related.

To help us understand how health and well-being are associated, we need to gather information about you, your feelings, and your experiences in life. To do this, we ask that you complete this questionnaire. We would like you to complete the questionnaire in your own time, before you come to your first research appointment at UCL.

The questions are mostly answered by marking a circle, or circling one of the possible answers.

All answers to these questions will be kept strictly confidential. It will not be possible to identify your responses from the reports we prepare. The information will go into the statistical reports of the study, and it will not be possible to identify your responses from any reports or publications. None of the information will be made available to anyone else apart from the research group.

Thank you very much again for your participation.

App. 2 continued

SECTION A *[Demographic information]*

This section has a series of questions that ask about you and your current situation.

Today's date? / /

1. What is your date of birth? DD/MM/YYY / /

2. What is your marital status at the moment?

   - ○ Currently married & living together, or living with someone in marital-like relationship
   - ○ Single
   - ○ Separated / Divorced / Formerly lived with someone in a marital-like relationship
   - ○ Widowed

3. To which of these ethnic groups do you consider you belong?

○ White British	○ White and Black Caribbean	○ Indian
○ White Irish	○ White and Black African	○ Pakistani
○ Any other white background	○ White and Asian	○ Bangladeshi
○ Caribbean	○ Any other Mixed background	○ Any other Asian background
○ African	○ Chinese	○ Any other
○ Any other Black background		______________________

App. 2 continued

[…]

5. What is your job/job title?

____

6. How many hours a week do you work at your place of employment, on average?

______________________________ *hours*

7 How many hours a week do you work at home, on average?

______________________________ *hours*

8. How old were you when you finished full-time education? ______________ *years*

9. What educational qualifications do you have? Please mark the circle next to your highest qualification.

- O None
- O CSEs or equivalent
- O GCSEs, O Levels, etc or equivalent
- O A levels
- O HNC/HND
- O GNVQ
- O Modern apprenticeship
- O Diploma
- O Degree
- O Postgraduate (e.g. MBA, Ph.D)
- O Other (please specify)

____

____________________ *rooms*

[…]

14. Do you have children? No O Yes O

____

15. What is the total current yearly amount you receive from your wage, benefit allowances, annual salary or other sources (e.g. investments) (before tax is deducted)?

Please mark one circle.

- O Less than £9,999
- O £10,000 - £14,999
- O £15,000 - £19,999
- O £20,000 - £24,999
- O £25,000 - £34,999
- O £35,000 - £49,999
- O £50,000 - £69,999
- O More than £70,000

App. 2 continued

SECTION B *[Neighbourhood Problems scale]*

SECTION C *[Work stress: Effort-reward imbalance & overcommitment]*

SECTION D *[Financial Problems scale]*

[…]

SECTION F *[Jenkins Sleep Problems scale]*

SECTION G *[Health behaviours: exercise and smoking]*

How often do you take part in sports or activities that are mildly energetic, moderately energetic or vigorous? (Mark one circle only for each item)

		Three times or more a week	Once to twice a week	About once to three times a month	Never / hardly ever
2.	Mildly energetic *(e.g. walking, woodwork, weeding, hoeing, bicycle repair, general housework)*	○	○	○	○
3.	Moderately energetic *(e.g. cycling, dancing, scrubbing, dancing, golf, decorating, lawn mowing, leisurely swimming)*	○	○	○	○
4.	Vigorous *(e.g. running, hard swimming, tennis, squash, digging, cycle racing)*	○	○	○	○

[…]

7. Have you ever smoked cigarettes regularly? *(Please mark only one circle)*

○ No, never
○ Yes, ex-smoker

8. ↳ How old were you when you stopped smoking cigarettes regularly? ________

9. ↳ About how many cigarettes a day did you usually smoke? ________

○ Yes, current smoker

10. ↳ About how many cigarettes a day do you usually smoke? ________

App. 2 continued

[…]

SECTION R ***[Positive and Negative Affect Schedule, PANAS]***

[…]

SECTION S ***[Center for Epidemiologic Studies Depression scale, CES-D]***

[…]

That was the final section in this questionnaire; please check you have completed all the sections before returning it to us. If you have any comments, or you would like to add anything to what you have told us, please add them in the space below.

Thank you very much for taking the time to participate in this research project, we appreciate the contribution you have made to our research on wellbeing and health.

Appendix 3: Multivariate analyses of resilience and cortisol (see Chapter 5)

The table shows the relationships between resilience and each cortisol measure adjusted for age, BMI, smoking status, parental status and mean awakening time. (Mean awakening time was calculated across the work and leisure day).

Cortisol measure (DV)	**Multivariate result**			**Univariate results**		
Total coritsol	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**
(N=146)	.999	(2, 136) = .035	.966	Work day	(1, .009) = .059	.808
				Leisure day	(1, .005) = .038	.845
CAR	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**
(N=130)	.999	(2, 122) = .062	.940	Work day	(1, 3.36) = .036	.850
				Leisure day	(1, 4.85) = .076	.783
Cortisol slope	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**
(N=146)	.972	(2, 138) = 1.96	.144	Work day	(1, <.000) = .249	.619
				Leisure day	(1, .001) = 3.89	.050*

*p≤0.05

Appendix 4: Multivariate analyses of the HRV results (see Chapter 6)

	Time period													
	Day							Evening						
HRV	**Multivariate result**				**Univariate results**			**Multivariate result**				**Univariate results**		
HF	**N**	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**	**N**	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**
	137	.973	(2, 130) = 1.84	.163	Work day	(1, 2.29) = 3.53	.062	179	.941	(2, 172) = 5.43	.005**	Work evening	(1, 6.92) = 10.6	.001***
					Leisure day	(1, .358) = .684	.410					Leisure evening	(1, .251) = .436	.510
LF	**N**	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**	**N**	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**
	140	.997	(2, 133) = .170	.844	Work day	(1, .115) = .338	.562	182	.952	(2, 175) = 4.37	.014*	Work evening	(1, 2.80) = 8.397	.004**
					Leisure day	(1, .004) = .013	.910					Leisure evening	(1, .108) = .298	.586
LF/HF	**N**	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**	**N**	**Wilk's λ**	**F**	**p**	**Day**	**F**	**p**
	134	.984	(2, 127) = 1.03	.360	Work day	(1, .012) = 1.38	.243	179	.971	(2, 172) = 2.57	.080	Work evening	(1, .046) = 5.15	.024*
					Leisure day	(1, .007) = 1.06	.305					Leisure evening	(1, .001) = .138	.710

*p<0.05, **p<0.01, ***p<0.001

<u>Appendix 5: Wellbeing Study participant information sheet</u>

Wellbeing Intervention Study: Participant Information Sheet

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

Positive psychological states and emotions are associated with better health and longer lifespan. Psychological studies have shown that regularly practising activities designed to increase positive feelings or behaviours can improve well-being. In our project, we want to see whether improving well-being is associated with healthier biological measures. This intervention study is part of two PhD projects supervised by Professor Andrew Steptoe from the Research Department of Epidemiology and Public Health, UCL.

Who can take part?

This study is being carried out with healthy women aged 18 to 45 years old who are working at UCL and nearby institutions. Volunteers should not be on any regular medicines or medications except for oral contraceptives. If you have suffered from a serious illness such as heart disease or cancer over the past two years, you will not be suitable for the study.

What will happen during the study?

The study lasts for 4 weeks. During the first week we will ask you to complete a short daily questionnaire on your mood and sleeping habits plus one longer questionnaire booklet that includes measures of lifestyle factors such as smoking and various psychological measures. During this first week, we will also take some biological measurements from you over one day. These measures include blood pressure, heart rate and saliva samples to look at the stress hormone cortisol. We will also ask you to wear a small activity monitor on your wrist for the first week.

During the second and third week, we will ask you to complete short writing tasks. These writing tasks will ask you to reflect on your everyday life. You will be allocated to one of two different writing tasks, each looking at different aspects of how you think about your life.

During the final week, we will ask you to repeat the questionnaire and biological measurements as in week 1. This is so that we can look for changes in these measures to evaluate any effects of the writing tasks.

On the first day of the study you will need to come to our research laboratory at the Research Department of Epidemiology and Public Health, UCL, situated at 1-19 Torrington Place <u>before</u> work. When you arrive in the building, one of our team members will take you to an office on the 3rd floor. If you happen to have a cold or flu or have had to take any medicines shortly before, please get in touch so that we can reschedule the appointment.

At the beginning of the first session we will measure your height and weight. Next, we will fit you with an activity monitor and a blood pressure monitor. You should wear the activity monitor for the next 7 days and nights, whereas the blood pressure monitor should be kept on for the rest of that day. The blood pressure monitor consists of an arm cuff, and a small monitor attached to your belt (it might be more comfortable for you if you wear a pair of trousers on that day). The blood pressure cuff and monitor are connected by a thin tube that is worn underneath a shirt/top. This device is not uncomfortable, but it will automatically inflate every 30 minutes to measure your blood pressure. It is important that you do not remove the device until you go to bed. We would like to ask you to refrain from taking the bath or shower on the day you will be wearing the blood pressure device. Should you need to take a shower/bath please remove the device.

We will also ask you to give us some samples of saliva over a 24 hour period, so that we can measure the stress hormone cortisol. The saliva samples are taken by chewing gently on a cotton roll for two minutes, then putting the wet cotton roll into a test tube. We want to collect 5 saliva samples over the day and 2 the next morning. We will ask you to come back to the research laboratory to return the blood pressure monitor and saliva samples, but we would be equally happy to collect them from your work place if that is going to be more convenient for you.

The collected information is completely confidential, results will not be available to anyone outside the study group and will only be used anonymously.

What if I change my mind during the study?

If at any point for any reason you do not want to carry on, then you may stop. There are no consequences of withdrawal from the study, other than forfeiting the honorarium payment (see below).

What happens to the information?

All the information we get from this study about you, including your name, will be confidential and will only be used for research purposes. The data will be collected and stored in accordance with the 1998 Data Protection Act. The data we collect from all volunteers will be combined, and it will not be possible to identify any individual within published results.

What happens at the end of the study?

Provided you have completed all the parts of the study we will give you an honorarium of £30. When the study is complete and all the results are analysed, we will send you a summary of our findings.

Can I take part if I am pregnant?

There are no risks to taking part in the study because you are pregnant. However, because pregnancy has effects on some of measures, we do not wish pregnant women to participate.

Appendix 6: Wellbeing Study questionnaire booklet: Pre-intervention

Note: Words shown in square brackets were not seen by the participants (these are notes added for convenience or clarity).

Well-being study

QUESTIONNAIRE BOOKLET: *Week 1*

PLEASE FILL OUT ONCE DURING THE FIRST WEEK

Instructions:

In this booklet we will be asking you questions related to your personal circumstances, your regular behaviour and your health and well-being. We will give you a similar questionnaire booklet to fill out during the last week of the study.

Please answer every question in the booklet, and read instructions carefully at the start of each set of questions, as they may differ. You should indicate your answers by either circling one answer or ticking a box as instructed.

If you have any questions on how to fill out any part of this booklet, please contact either Jennie or Marta for guidance:

[Contact details here]

We would like to assure you that all your answers are strictly confidential. It will not be possible to identify your responses from the reports we prepare. We will use the information to conduct statistical analyses and to write academic articles, but it will not be possible to identify your responses from any reports or publications. None of the information will be made available to anyone else apart from the research group.

Thank you very much again for your participation.

App. 6 continued

SECTION 1 *[Demographic information]*

[The questions on demographic information were the same as in the Daytracker study (see appendix 2, section A) except for employment where response choices were given (see below). Questions were asked about: date of birth, marital status, parental status, ethnicity, religion, employment, income, number of hours worked per week and education].

[…]

6. Which category best describes your employment?

- Administrative/clerical
- Technician (e.g. lab technician, IT)
- Manual & craft (e.g. cleaner, security)
- Managerial
- Non clinical research (e.g. research associate/assistant)
- Non clinical academic/teaching (e.g. lecturer, teaching assistant)
- Medical/clinical (e.g. clinical research associate, research nurse)
- Postgraduate student
- Other, please describe:

SECTION 2 *[Health behaviours]*

[The questions in this section on exercise and smoking behaviour were the same as the Daytracker study questionnaire (see appendix 2, section G). Additionally we asked about alcohol use – see below].

[…]

The next questions are about drinking alcohol, including beer, wine, spirits and any other alcoholic drink.

6. Do you drink alcohol?

   - No
   - Yes

7. If yes, on how many days over the past two weeks (14 days) did you have a drink?

8. On the days that you did drink, how many drinks did you have, on average? (One drink = one small glass of wine, half a pint of beer or cider, a single measure of spirits)

drinks

____

SECTION 3 ***[Pittsburgh Sleep Quality Index (not reported in this thesis)]***

SECTION 4 ***[Scale of Positive and Negative Experience]***

SECTION 5 ***[Gratitude Questionnaire]***

SECTION 6 ***[Flourishing Scale]***

SECTION 7 ***[Life Orientation Test (optimism)]***

SECTION 8 ***[Satisfaction with Life Scale]***

SECTION 9 ***[Perceived Stress Scale]***

SECTION 10 ***[Hospital Anxiety & Depression Scale]***

[...]

15. In general, how would you say that your health has been in the **past week**? Please circle the answer which best describes your health.

Poor   Fair   Good   Very good   Excellent

That was the final section in this questionnaire; please check you have completed all the sections before returning it to us. If you have any comments, or you would like to add anything to what you have told us, please add them in the space below.

Thank you very much for taking the time to participate in this research project, we appreciate the contribution you have made to our research on wellbeing and health.

Additional comments:

Appendix 7: Daily emotions and sleep diary extract

[***Note:*** Only Day 1 is shown here as an example. Days 2 to 7 included repetitions of the same sections as Day 1, with the addition of a daily sleep questionnaire (not shown here)].

Well-being study

DAILY EMOTIONS & SLEEP DIARY

PLEASE FILL THIS OUT EVERY DAY

Instructions:

At the end of each day we would like you to record how you felt during the day, plus some details on your sleep the *previous* night.

This diary has space to record how you felt everyday for 7 days and details of your sleep for 7 nights. On the morning of day 8, we would like you just to record your sleep from the night before (this is so that we have a record of your sleep for 7 nights).

There is space for you to record the date on each day, so you can keep track of your answers. Don't worry if you forget to fill out one day, please carry on with the next day, leaving the answers *blank* on the missed day.

If you have any questions or problems with this diary, please contact us:

[Contact details here]

Your starting day is..

DAY 1 **Today's date is: ___________________________**

Below are a number of words that describe different feelings and emotions. Read each word and then indicate how much you felt that way ***today*** by circling a score for that word.

		0 very slightly / not at all	**1 a little**	**2 moderately**	**3 quite a bit**	**4 extremely**
1.	Happy	0	1	2	3	4
2.	Tired	0	1	2	3	4
3.	Calm	0	1	2	3	4
4.	Sad	0	1	2	3	4
5.	Energetic	0	1	2	3	4
6.	Hostile	0	1	2	3	4
7.	On edge	0	1	2	3	4
8.	Fatigued	0	1	2	3	4
9.	Hassled	0	1	2	3	4
10.	Lively	0	1	2	3	4
11.	Angry	0	1	2	3	4
12.	Cheerful	0	1	2	3	4
13.	Tense	0	1	2	3	4
14.	At ease	0	1	2	3	4
15.	Unhappy	0	1	2	3	4
16.	Stressed	0	1	2	3	4

17. Was today a normal day for you? Please circle the answer that best describes your day.

Yes, just a normal day	No, my day included bad (stressful) things	No, my day included good things

App. 7 continued

DAY 1 continued....

Did you remove your Actiwatch *today*? If so, indicate why and for how long. For example: Reason: Swim, Time off: 3pm, Time on: 4.15pm. If you do not want to give a reason, please leave this part blank.

1. Reason……………...............Time off………..........Time on………..........
2. Reason……………...............Time off………..........Time on………..........
3. Reason……………...............Time off………..........Time on………..........
4. Reason……………...............Time off………..........Time on………..........
5. Reason……………...............Time off………..........Time on………..........

Appendix 8: Questionnaire booklet: Post-intervention

[***Note*****:** The post-intervention booklet was the same as the pre-intervention booklet, with the following exceptions:

1) We did not ask about demographic and health behaviour information again
2) The instructions were slightly different (see below)
3) We added a section on writing task compliance (shown below)]

Well-being study

QUESTIONNAIRE BOOKLET: *Week 4*

PLEASE FILL OUT ONCE DURING THE WEEK

Instructions:

In this booklet we will be asking you questions related to your health and wellbeing. We gave you a similar questionnaire booklet to fill out during the first week of the study.

Please answer every question in the booklet, and read instructions carefully at the start of each set of questions, as they may differ. You should indicate your answers by either circling one answer or ticking a box as instructed.

If you have any questions on how to fill out any part of this booklet, please contact either Jennie or Marta for guidance:

[Contact details here]

We would like to assure you that all your answers are strictly confidential. It will not be possible to identify your responses from the reports we prepare. We will use the information to conduct statistical analyses and to write academic articles, but it will not be possible to identify your responses from any reports or publications. None of the information will be made available to anyone else apart from the research group.

Thank you very much again for your participation.

App. 8 continued

[The booklet here is then the same as sections 3 to 10 of the pre-intervention booklet, appendix 6. The final questions of the post-task questionnaire booklet ask about task completion, as follows.]

Finally, we are interested in how you found the writing task. Your honesty is appreciated.

16. How many times did you do the writing exercises?

Once Twice 3 times 4 times 5 times 6 times

17. How much effort did you put into the writing task overall?

Very little effort Quite a bit of effort A lot of effort

That was the final section in this questionnaire; please check you have completed all the sections before returning it to us. If you have any comments, or you would like to add anything to what you have told us, please add them in the space below.

Thank you very much for taking the time to participate in this research project, we appreciate the contribution you have made to our research on wellbeing and health.

Additional comments:

____

____

____

____

____

____

Appendix 9: Saliva sample diary extract

Well-being study

Saliva sample diary

(& record sheet should you need to remove your blood pressure monitor)

THE SALIVA SAMPLES.

Over the course of today and tomorrow morning you will be collecting saliva samples at 7 different times, starting with the first sample during your meeting with us in the research lab. Please collect the samples at the times listed in the table opposite. It may be helpful to set an alarm on your watch or phone to remind you. Each time you collect a sample, please answer the questions in this booklet. There are separate questions (one set per page) for each sample.

Please place the tube for the waking sample (Tube 6) and this booklet next to your bed before you go to sleep tonight.

Your honesty is very important to us in analysing the results. Please write down the actual collection time, even if it is different to the designated time, and answer the questions as accurately as possible.

Instructions:

1. Do not smoke, eat or drink anything for **30 minutes** before you collect the sample.
2. Remove the small plastic cap, and place the cotton swab in your mouth, avoiding touching it with your hands.
3. Gently chew on the swab until it is soaked, this will usually take about 2 minutes. While you are doing this, answer the questions for this sample in this booklet.
4. Once the swab is soaked, place it back in the tube, trying not to use your hands. Put the cap on securely, and place the tube in the plastic bag provided.
5. Store the bagged tubes in a cold place or in a refrigerator until you bring it in.

App. 9 continued

SALIVA SAMPLE COLLECTION TIMES

Sample Time	Tube No.	Instructions
TODAY:		
Before work	1	We will collect the first sample when you come to the lab today.
10am Today	2	Remember to take this with you if you are going out.
12pm Today	3	Remember to take this with you if you are going out.
5pm Today	4	Remember to take this with you if you are going out.
Bedtime Today	5	Take this sample just before going to bed. Remember to put **tube 6** and your saliva sample diary next to your bed, ready for when you wake up.
TOMORROW:		
Waking	6	This sample should be collected as soon as you wake up, and ***before*** you get out of bed.
30 minutes after waking	7	Take this sample 30 minutes after your waking sample. Do not have any caffeinated drinks, brush your teeth or eat before you collect this sample.

App. 9 continued

SAMPLE 1 (BEFORE WORK, IN THE LAB)

1. ***What was the exact time you collected the sample?*** a.m. / p.m.

In the last 30 minutes did you feel…..

		Not at all				***Very much***
2.	Happy?	**1**	**2**	**3**	**4**	**5**
3.	Tired?	**1**	**2**	**3**	**4**	**5**
4.	Sad?	**1**	**2**	**3**	**4**	**5**
5.	Stressed?	**1**	**2**	**3**	**4**	**5**
6.	Frustrated or angry?	**1**	**2**	**3**	**4**	**5**

In the 30 minutes prior to collecting the sample did you…

7.	Brush your teeth?	**No**	**Yes**
8.	Drink any tea, coffee or other caffeinated drinks?	**No**	**Yes**
9.	Take any medicines?	**No**	**Yes**
10.	Eat a meal?	**No**	**Yes**
11.	Drink any alcohol?	**No**	**Yes**
12.	Do any exercise?	**No**	**Yes**
13.	Smoke any cigarettes?	**No**	**Yes**

App. 9 continued

[Questions for samples 2-5 and sample 7 (wake+30) were then exactly the same as sample 1 (except that they were entitled with the appropriate sample number and collection time).

The waking sample (sample 6), included an additional question on delay as follows:

> *1a) Was there a delay between waking up and collecting your first sample? (Yes or no)*
>
> *1b) If yes, how long was the delay?*

At the end of the saliva booklet, there was a space to note whether the blood pressure monitor had been taken off, and detailed instructions as below.]

THE BLOOD PRESSURE MONITOR

Over the course of today we would like you to wear a blood pressure monitor until you go to bed. This monitor was fitted to you in our research lab, and you do not need to do anything to it. Please try not to take the cuff and monitor off, unless you take a shower/bath or go swimming. When you put the cuff back on, make sure you fit it on the same arm as before. The white arrow on the cuff should be pointing towards the middle of your inner elbow crease (where your artery is).

If the cuff is too loose, or uncomfortably tight, it can be adjusted slightly using the velcro fastening.

If you did need to take the monitor or cuff off, please note the time that you did this here (e.g. Reason: swimming, Time off: 3pm, Time on: 4.15pm). If you do not want to give a reason you may simply leave it blank.

6. Reason……………….Time off………...Time on……….

7. Reason……………….Time off………...Time on……….

8. Reason……………….Time off………...Time on……….

<u>Appendix 10: Gratitude writing task booklet</u>

Instructions:

You have been randomly assigned to try to cultivate a sense of gratitude now, and during the next few weeks. 'Cultivate a sense of gratitude' means that you make an effort to think about the many things in your life, both large and small, that you have to be grateful for. These might include particular supportive relationships, sacrifices or contributions that others have made for you, facts about your life such as your advantages and opportunities, or even gratitude for life itself, and the world that we live in.

For example: I am grateful....'To my husband for paying me a compliment on my new dress', 'That I found the strength to deal with a difficult situation at work', 'That I finally cleaned my flat', 'For the kindness of my parents', 'I am grateful that the trees are finally green', 'I am grateful I was given a seat in the bus this morning', 'I am grateful my cat is no longer unwell', 'After watching this evening news I am grateful I live in a peaceful country'…

In all of these cases you are identifying *previously unappreciated* aspects of your life, for which you can be thankful. You may not have thought about yourself in this way before, but research suggests that doing so can have a positive effect on your mood and life satisfaction.

We'd like you to practice writing an example of something you are grateful for in your life.

Practice exercise:
[Box to write practice exercise]

When you get home, we'd like you to write about 3 things you are grateful for. We would like you to do this 3 times per week. You should spread out your writing exercises e.g. every other day such as Monday, Wednesday, Friday. We would like you to do this for 2 weeks (6 writing exercises in total). Please try to write something different every time.

We have provided boxes for you to write your sentences on the next 2 pages, you do not have to fill the entire space. Please provide the day of the week you wrote your exercise, so that you can keep track.

[Another 2 pages follow, one for each week. On each page are 3 blank boxes labelled 'exercise 1, 2 and 3' with a space to write the date – as in the example below]

Week 1

Exercise 1: Today's date is.....................
[Blank box to write exercise with the numbers 1, 2 and 3 on the inside left of the box to remind the participants to try to think of 3 things for which they are grateful]

Appendix 11: Daily events writing task booklet

Instructions:

You have been randomly assigned to write about events that have happened during your day. We want you to start focusing your attention on everyday events, and become more aware of what is happening around you. For example, on your way to work instead of rushing to a bus stop, or a train station, try not to think about or plan your day, but pay attention to your surroundings. Perhaps listen if birds are singing, look at the flowers in people's front gardens, or just simply observe the things around you. You may not have thought about yourself in this way before, but research suggests that doing so can have a positive effect on your mood and life satisfaction.

For example, today I noticed….'The wind rustling in the trees', 'The colours of the flowers', 'My neighbour's children playing in the garden', 'The noise of the traffic', 'The first signs of autumn', 'The smell of grass after the rain', 'Other people talking in the train', 'The building opposite my office was being cleaned'.

We'd like you to practice writing an example of an event that happened today.

Practice exercise:

Today is......................

[Box to write practice exercise]

When you get home, we'd like you to write about 3 different events that happened that day. We would like you to do this 3 times per week. You should spread out your writing exercises e.g. every other day such as Monday, Wednesday, Friday. We would like you to do this for 2 weeks (6 writing exercises in total). Please try to write something different every time.

We have provided boxes for you to write your sentences on the next 2 pages, you do not have to fill the entire space. Please provide the day of the week you wrote your exercise, so that you can keep track.

[The layout of the rest of the booklet is then exactly the same as the gratitude booklet, see appendix 10]