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Contents

List of Publications and Presentations supported by this grant	1
Study background:	3
Study 1: Attachment style, well-being and salivary cortisol secretion	5
Background:	5
Aim:	6
Method:.....	7
Results:.....	8
Results 1: Attachment style: relationships with well-being or ill-being	8
Implications/Conclusions:	10
Results 2: Impact of non-adherence to the saliva sampling protocol on diurnal cortisol patterns	11
Implications/ conclusions	12
Results 3: Diurnal cortisol patterns: relationships with trait and state well-being/ill-being.....	13
Implications/Conclusions:	14
Study 2: Understanding the cortisol awakening response.....	16
Background	16
Aims:.....	17
Method:.....	17
Results:.....	18
Implications/Conclusions	18
Study 3: Well-being, aging and cortisol secretion.....	19
Background	19
Method:.....	19
Results:.....	20
Implications/Conclusions:	20

List of Publications and Presentations supported by this grant

Peer-reviewed papers:

- **Smyth, N.**, Clow, A., Thorn, L., Hucklebridge, F., & Evans, P. (2013). Delays of 5-15min between awakening and the start of saliva sampling matter in assessment of the cortisol awakening response. *Psychoneuroendocrinology*.
- **Smyth, N.**, Hucklebridge, F., Thorn, L., Evans, P., Clow, A. (in press). Salivary cortisol as a biomarker in social science research. *Social and Personality Psychology Compass* 1–21, 10.1111/spc3.12057

Papers in preparation:

Plan to submit papers to *Psychoneuroendocrinology* the end of August 2013 with the following authors **Smyth, N.**, Hucklebridge, F., Thorn, L., Evans, P., Clow, A.

- Diurnal patterns of cortisol; relationships with trait and state well-being in a young healthy females.
- Exploring relationships between hair cortisol and well-being/ill-being in young and old females.

Conference Oral Presentations:

- **Smyth N**, Thorn L, Evans P, Hucklebridge F, Clow A. Patterns of Salivary Cortisol Secretion in High and Low Well-being Students. Psychobiology British Psychological Society Annual Conference, Lake District, Sept 2011.
- **Smyth N**, Evans P, Thorn L, Hucklebridge F, Clow A. Impact of saliva sampling delay on assessment of the cortisol awakening response (CAR) in a healthy student sample. Psychobiology British Psychological Society Annual Conference, Lake District, Sept 2012.

- **Smyth, N.**, Clow, A., Thorn, L., Hucklebridge, F., Evans, P. The CAR: impact of short delays and associations with trait and state well-being. Cortisol Network meeting, Imperial College, January 2013.
- Evans P, **Smyth, N**, Thorn L, Hucklebridge F, Clow, A. Delays of 5-15 minutes between awakening and the start of saliva sampling matter in assessment of the cortisol awakening response. American Psychosomatic Society Annual Conference, Miami, March 2013.

Conference Poster Presentations:

- **Smyth N**, Thorn L, Evans P, Hucklebridge F, Clow A. Discrepancies between self-reported and objective sampling delay for the cortisol awakening response. American Psychosomatic Society Annual Conference, Athens, March 2012.
- **Smyth N**, Oskis A, Clow A. The Relationship between Trait and State Well-being and Attachment Style in Students. Selected and presented for a data blitz session at the American Psychosomatic Society Annual Conference, Athens, March 2012.
- **Smyth N**, Evans P, Thorn L Hucklebridge F, Clow A. State Well-being or Ill-being does not predict cortisol patterns in a young healthy sample. American Psychosomatic Society Annual Conference, Miami, March 2013.
- **Smyth N**, Evans P, Thorn L Hucklebridge F, Clow A. Trait Hedonic and Eudemonic Well-being and Diurnal Cortisol Patterns. American Psychosomatic Society Annual Conference, Miami, March 2013.

Study background:

Cortisol secretion follows a distinct circadian rhythm characterized by a nadir in early sleep, gradually increasing concentrations during late sleep, peak levels at 30-45 minutes post awakening (known as the cortisol awakening response: CAR) and a declining pattern. Measurement of cortisol in saliva enables determination of the CAR and diurnal decline within the domestic setting with unsupervised repeated sampling over the day. Typically the CAR, diurnal decline have been studied in relation to trait and state ill-being. Both high and low levels of cortisol as well as disrupted circadian rhythm is associated with poor psychological and physical health (McEwen, 1998), for example, depression (Holsboer, 2000; Huber, Issa, Schik, & Wolf, 2006), chronic fatigue syndrome (Crawford & Henry, 2004; Demitrack et al., 1991) and poor cancer prognosis (Abercrombie et al., 2004; Sephton & Spiegel, 2003). In recent years the benefits of well-being on health are becoming increasingly evident (e.g. Pressman & Cohen, 2005), which has spanned interest in examining associations between well-being and cortisol secretion (Dockray & Steptoe, 2010). However, findings are inconsistent between and within studies, particularly for the CAR.

A potential explanation for inconsistencies is participant non-adherence to the saliva sampling protocol. Participants are typically inaccurate in their self-reported adherence, and delays (> 10-15 min) in saliva sampling result in misleading CAR measurements (e.g. Broderick, Arnold, Kudielka, & Kirschbaum, 2004; DeSantis, Adam, Mendelsohn, & Doane, 2010; Dockray, Bhattacharyya, Molloy, & Steptoe, 2008; Kudielka, Broderick, & Kirschbaum, 2003; Okun et al., 2010). However, delays in sampling across the day do not influence measurement of the diurnal decline, this is expected given the steady decline in cortisol over the day (Jacobs et al., 2005).

Consequently the primary objective of the work undertaken here has been to explore and enlighten relationships between the diurnal pattern of cortisol secretion with measures of both state and trait well-being independently of ill-being. In the first

instance associations between well-being and cortisol were examined in healthy, psychopathology-free young females but the work was extended to investigate the impact of aging on associations between cortisol secretion and well-being in healthy older females. The impact of non-adherence to saliva sampling protocols on measurement of the CAR and other aspects of the diurnal secretory profile was another objective of the work presented here.

Overall aims of research:

The overarching aim of this research was to explore associations between cortisol secretion and well-being in healthy adults, given that well-being may have an effect on future health by directly influencing cortisol secretion. However, exploring these relationships under strict monitoring of adherence to protocol is crucial due to the impact of sampling delays on measurement of salivary cortisol.

The overall aims of this research were:

- (1) To expand significantly the collection of published data on the association between cortisol patterns and well-being in healthy participants using well-established methodology and strict monitoring of participant adherence to protocol.
- (2) To investigate the causal direction of the relationship between well-being and cortisol in an intervention study designed to enhance participants well-being through a positive psychological intervention.
- (3) To inform best practice methodology for the ever-increasing number of studies in this area of research

Study 1: Attachment style, well-being and salivary cortisol secretion

Background:

Insecure attachment style has been implicated with ill-being however; studies have mostly measured well-being in terms of ill-being, such as depression less focus has been on the hedonic (subjective well-being) and eudemonic (psychological well-being) aspects of well-being in relation to attachment style and cortisol. The evidence for the promising relationship between well-being and cortisol is inconsistent and conflicting. For example, both ill-health and well-being are associated with a decreased and increased CAR (see Chida & Steptoe, 2009; Dockray & Steptoe, 2010 for reviews) This makes it difficult to compare and interpret the findings, thus several methodological issues need to be considered. Further, samples have included typically middle-aged and older adults, with stronger relationship between well-being and cortisol in older adults (Ryff, Singer, & Love, 2004). No study to date has investigated associations between well-being and cortisol specifically in a healthy younger sample.

The measurement of well-being is often limited to measuring hedonic well-being and studies typically ignore the role of eudemonic well-being. Although debate surrounding the distinction of hedonic and eudemonic well-being remains (Kashdan, Biswas-Diener, & King, 2008; Keyes & Annas, 2009) a combination of both aspects is important (King & Napa, 1998). Furthermore, some researchers (e.g. Ryff, et al., 2004) demonstrate stronger relationships between cortisol secretion and eudemonic well-being compared to hedonic well-being. Measuring state as well trait well-being is also recommended since cortisol secretion is considerably influenced by state psychosocial variables, indicating that cortisol (especially the CAR) is very responsive to day-to-day variations in psychological state (Hellhammer et al., 2007). Only a few studies have attempted to consider the role of state well-being; those that have demonstrate stronger relationships between state well-being and cortisol compared with trait well-being (e.g. Steptoe, Gibson, Hamer, & Wardle, 2007).

Non-adherence to the saliva sampling protocol is a key issue in this type of research. It can lead to misleading CAR estimates, which may explain the inconsistencies in the literature regarding the relationship between the CAR and well-being/ill-being. Studies have generally relied on self-report methods of monitoring adherence to the saliva sampling protocol. Some studies have used electronic estimates of awakening or saliva sampling times, but only one has utilized both (Griefahn & Robens, 2011). However, no study has accounted for non-adherence in the relationship between cortisol patterns and well-being using both track caps and actigraph.

Aim:

The main aim of this study was to explore associations between the diurnal pattern of cortisol and subjective and psychological well-being independent of ill-being in healthy young individuals in the domestic setting. In this study participant adherence to protocol using both electronic estimates was monitored to examine the impact of non-adherence on cortisol patterns and to account for non-adherence in the relationship between cortisol patterns and well-being. A secondary aim of this study was to explore the relationship between attachment style, well-being, and cortisol profiles.

- To monitor and examine the impact of non-adherence to the saliva sampling protocol in ambulatory studies.
- Investigate the impact of moderate sampling delays on the CAR.
- Explore the relationship between attachment style with ill-being/well-being in young healthy females.
- Explore the relationship between diurnal patterns of salivary cortisol and well-being independent of ill-being in young healthy females.
- Explore the relationship between diurnal patterns of salivary cortisol and attachment style in young healthy females.

Method:

Students were recruited from the research participation scheme at Westminster University. Recruitment was conducted in two phases.

Phase 1:

240 male (N=43) and female (N=197) students (mean 21.0 ± 4.1 years) completed several standardised questionnaires of subjective and psychological well-being/ill-being, and attachment style. Factor analysis was performed which revealed that the both aspects of well-being and ill-being measures loaded strongly onto one factor, this composite factor was categorized as participants scoring high or low levels of well-being.

Phase 2:

50 female participants (average 21 yrs) categorised as high well-being or low well-being were recruited to collect saliva samples and rate their mood. Participants individually attended a one-to-one research session (duration 15-25 minutes). They provided informed consent and received full verbal and written instructions on the procedures and practiced the saliva sampling technique and calculation of saliva sampling times. Saliva samples were collected on 0, 15, 30, and 45 minutes and 3 and 12 hours post-awakening on four days (2 weekdays and 2 weekend days: start day was counterbalanced) to assess the CAR magnitude and diurnal decline. Participants were instructed to refrain from smoking, exercising and to remain nil-by-mouth except water 30 min prior to saliva sampling. State mood was assessed by participants rating mood adjectives across the day and were completed electronically (Actiwatch-Score) to ensure completion in real time. Participants were sent SMS-messages reminding them to prepare for the study and to collect the 3 and 12 hour post-awakening samples. As well as the usual self-report diary method, adherence to the saliva sampling protocol was monitored electronically; awakening times were estimated by actimeters and saliva sampling was monitored by Medication Event Monitoring (MEMs) Caps. Participants were informed about the importance of

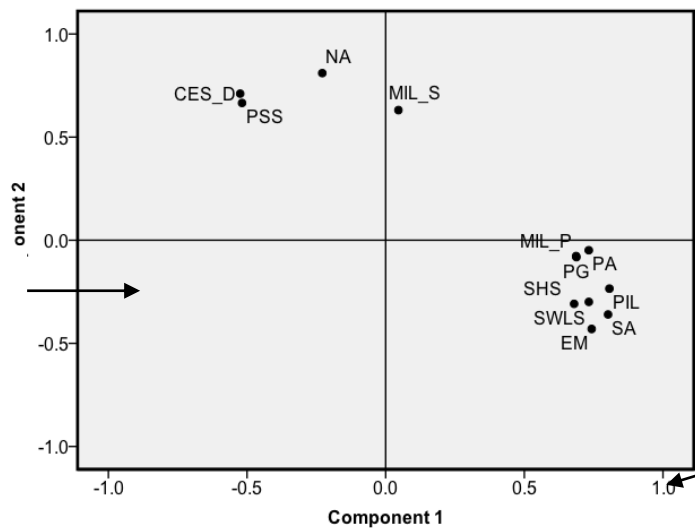
following the required protocol and that the electronic devices would be used to monitor their adherence to the protocol.

Results:

Results 1: Attachment style: relationships with well-being or ill-being

Factor that trait being strongly (see

ill-being factor →



analysis showed well-being and ill-measures loaded onto two factors (Figure 1).

well-being factor →

Figure 1 Component plot from factor analysis showing two factors

SHS = subjective happiness scale; PA = positive affect; SWLS = satisfaction with life scale; MIL-P = meaning in life – presence; MIL-S= meaning in life – search; EM = environmental mastery; PG = personal growth; PIL = purpose in life; SA = self-acceptance; NA = negative affect; PSS = perceived stress scale; CES-D = centre for epidemiologic studies depression scale.

Participants securely attached exhibited more well-and less ill-being than both the insecure anxious and avoidant attachment style groups. Well-being or ill-being did not differ between the insecure anxious or avoidant attachment style groups (see Figure 2).

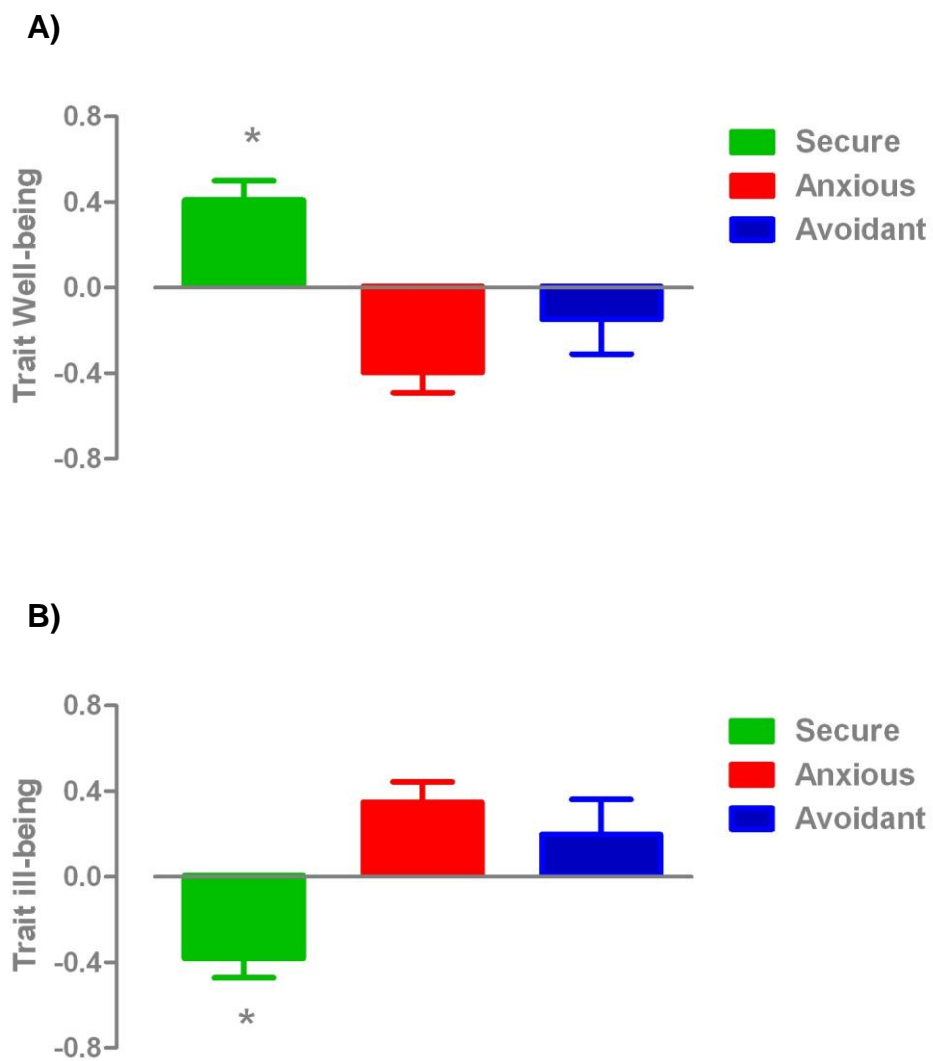


Figure 2 Attachment style groups (a) differences in well-being (b) differences in ill-being

There was also a significant difference in average state well-being between the attachment style groups. Significant differences in state well-being were found between the secure and insecure anxious (but not avoidant) attachment style groups; the anxious group exhibited lower well-being than those who were securely attached (see Figure 3). There were no significant differences in average state ill-being between the attachment style groups.

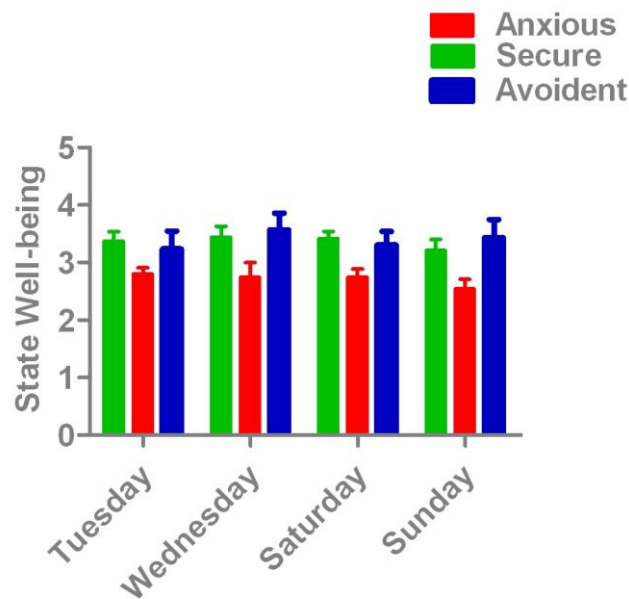


Figure 3 Attachment style groups: differences in state well-being measured over four study days

Implications/Conclusions:

The results show that those with a secure attachment style presented with the highest levels of both trait and state well-being. The results also indicate that attachment style may be more closely associated with state well-being than ill-being. Furthermore, this study highlights the importance of measuring both trait and state well-being.

Results 2: Impact of non-adherence to the saliva sampling protocol on diurnal cortisol patterns

Comparison of self-reports and electronic devices revealed that saliva sampling times were not different for self-reports and MEM Caps. However, self-reported awakening time was later than actigraph estimated awakening. Delays during the post-awakening period were attributed to delays between awakening

We investigated the impact of previously 'tolerable' delays on the CAR. Estimates of CAR magnitude were significantly *greater* on non-adherent days (delay of 5-15 min) compared to adherent days (delay < 5 min). On non-adherent compared to adherent days cortisol on average peaked earlier, at sample 3 rather than at sample 4 (see Figure 3).

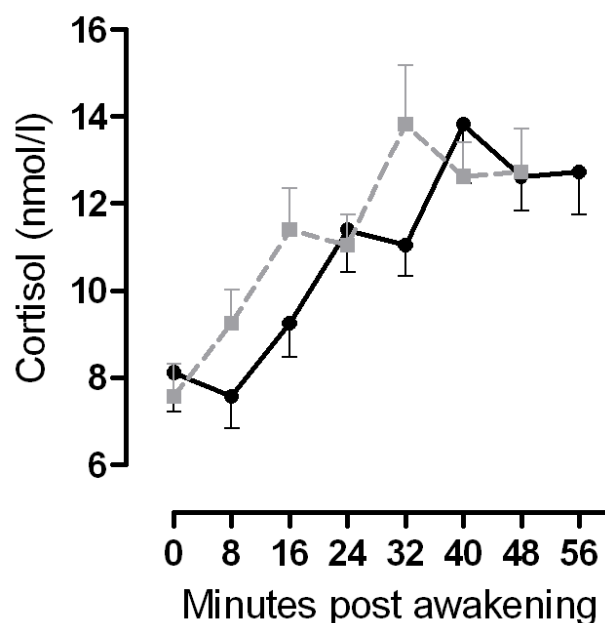


Figure 3 The solid black line shows the real-time pattern of cortisol secretion derived from Study 1, plotted at 8 minute intervals. The dotted grey line illustrates the impact of a delay of 8 minutes between awakening and collection of S1: the line has been shifted 8 minutes to the left.

We also investigated if delays in saliva samples collected across the day impacted on the diurnal decline or mean diurnal decline. Consistent with previous research (Jacobs, et al., 2005) there was no effect of delay on diurnal cortisol measures. This is expected given the steady decline over cortisol over the day.

Implications/ conclusions

This study highlighted that accurate determination of the CAR requires particular attention to the assessment of participant awakening time. Informing participants that their adherence to the protocol is being electronically measured improves their accuracy in reporting their saliva sampling times and collection of samples according to the desired times.

The novelty of these findings is that previously thought delays do in fact impact on the CAR, in terms of an overestimated CAR magnitude and earlier timing of the CAR peak. This finding merits further investigation since the timing of the peak has been implicated in gender, work overload, hormonal status and measures of cognitive function (Evans, Clow, Hucklebridge, & Loveday, 2012; Oskis, Loveday, Hucklebridge, Thorn, & Clow, 2009; Pruessner et al., 1997; Schulz, Kirschbaum, Pruessner, & Hellhammer, 1998), and is likely to be increasing investigated. Although the implications of this study are inconvenient in terms of the practicalities for accurate estimation of the CAR within the domestic setting it may shed light on why there is so much inconsistent evidence for the association between the CAR and a range of psychosocial and health variables.

These results suggest a time lag between awakening and rise in cortisol secretion. To investigate a time lag smaller interval of saliva sampling in the post-awakening period is necessary. (investigated in study 2)

Results 3: Diurnal cortisol patterns: relationships with trait and state well-being/ill-being

Figure 4 shows the difference in trait well-being and ill-being differed between the well-being groups. This shows that the categorization of well-being groups and selection of participants in phase I was successful.

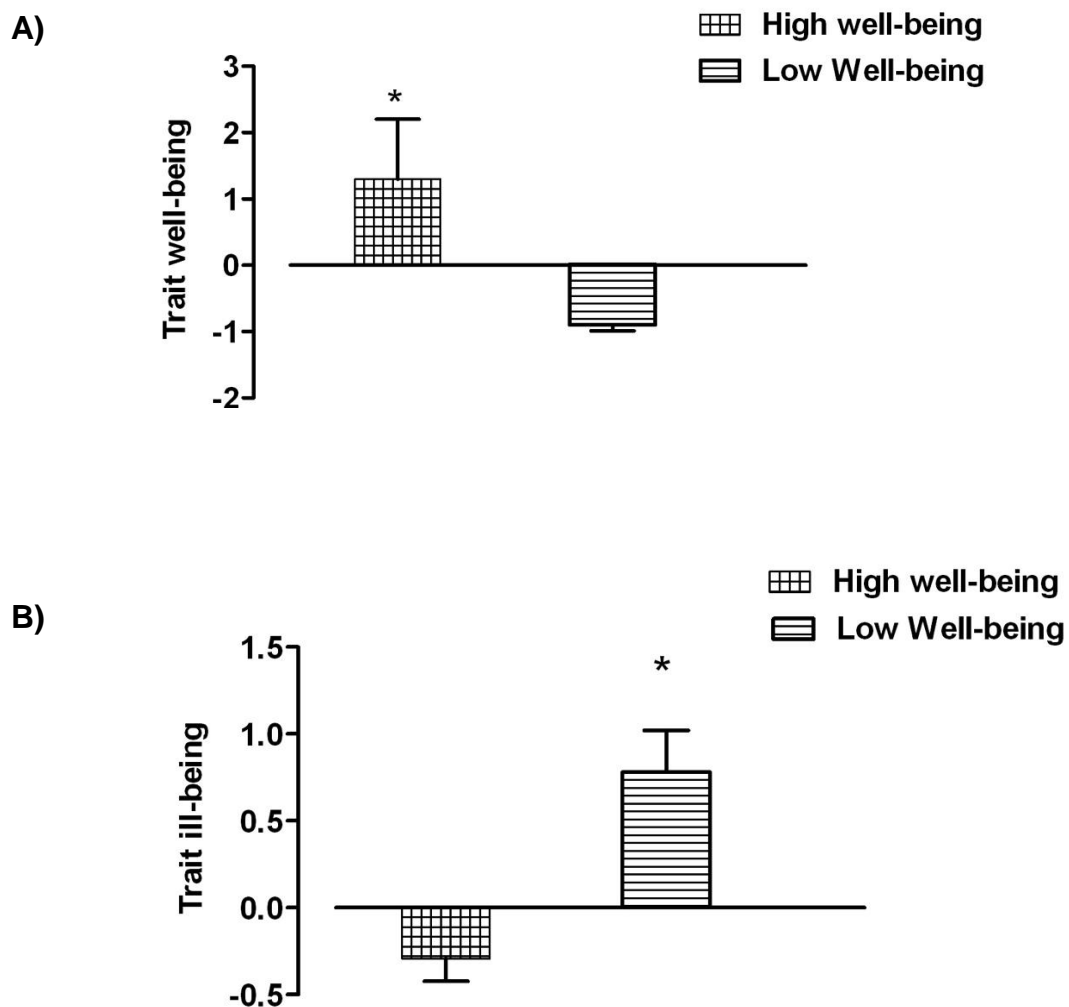


Figure 4 Differences in (a) trait well-being and (B) trait ill-being between high and low well-being groups *p < .001

Four composite measures of cortisol were calculated from the 4 days of cortisol: (1) awakening cortisol levels (2) CAR mean increase (3) diurnal decline (4) mean diurnal cortisol. Figure 5 shows the daily pattern of cortisol secretion over the 4 study days.

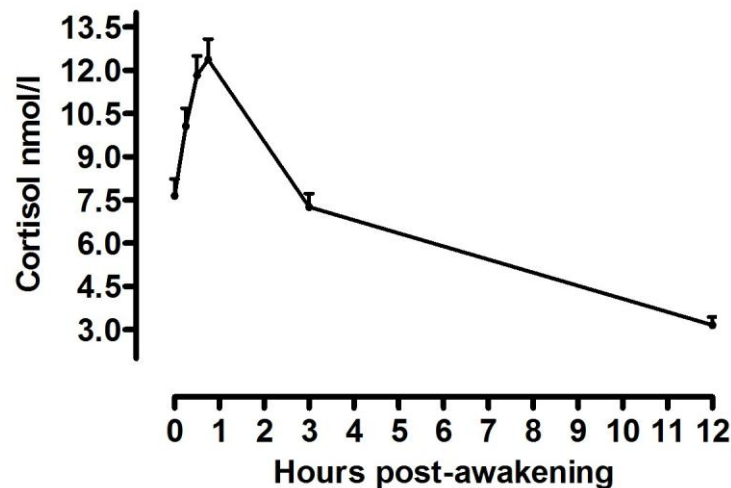


Figure 5 Diurnal pattern of cortisol (sample with < 15 min delay)

Mixed regression models analysis was conducted to explore the relationships between the composite measures of cortisol and (1) attachment style and (2) trait/state well-being/ill-being. Analyses involving the CAR were limited to delay < 15 min, and delays of 5-15 min were used as a covariate in the analyses. None of the composite measures of cortisol were associated with attachment style or any of the well-being or ill-being measures.

Implications/Conclusions:

This study failed to replicate the previous association between higher levels of well-being, lower levels of ill-being and patterns of cortisol secretion in a young healthy female sample. This was not due to non-adherence since the study electronically-monitored adherence and excluded non-adherent individuals. The null findings may

be attributed to the age of the participants such that associations only emerge in middle-aged and older individuals, as previously shown (Ryff, et al., 2004).

These findings could be explained in relation to the neurotoxicity/vulnerability hypothesis (Lupien, McEwen, Gunnar, & Heim, 2009). The presence of well-being and/or ill-being does not impact on the HPA-axis until later life (i.e. neurotoxicity). The HPA-axis is proposed to be more resilient in younger individuals so the associations between well-being or ill-being and cortisol are weaker, but in middle-aged and older individual's exposure to well-being or ill-being over time impacts on the HPA-axis, thus relationships are stronger in middle-aged and older individuals.

However, in vulnerable individuals (e.g. insecure attachment styles and/or exposure to early life stress) the HPA-axis is programmed during childhood to make it more vulnerable to dysregulation. In these vulnerable individuals dysfunction of the HPA-axis precedes and predicts later psychopathology (e.g. ill-being, low well-being aberrant cortisol profiles). In this study we found that insecurely attached individuals had lower well-being but there were no differences in their cortisol profiles. This group of insecurely attached individuals may not have been vulnerable enough to show a relationship with cortisol at this stage in their lifespan. Also, the measurement of vulnerability was limited to attachment style which may not have captured the severity of vulnerability e.g. early life stress.

These findings meant that a change in direction from the initial proposal of experimentally manipulating mood to investigate the causal direction of the relationship between well-being and cortisol was required. Since no relationships were found between well-being and cortisol secretion in a young healthy sample it was necessary to explain this finding by comparing the well-being and cortisol relationship in young and older samples (which was explored in study 3).

Study 2: Understanding the cortisol awakening response

Background

The findings that moderate delays resulted in erroneous CAR in Study 1 (results 2) provided the impetus for this study. The finding that moderate delay in saliva sampling lead to misleading CAR estimates are suggestive of a 'time lag' in salivary cortisol secretion between awakening and the start of increased cortisol secretion, which characterizes the CAR. In other words awakening sets off a chain of events which leads to increased cortisol secretion, which takes 5-15 minutes to manifest as increased cortisol concentrations in saliva.

This proposed 'time lag' would explain the finding that awakening cortisol levels were not different between the adherent and moderately non-adherent day data in Study 1. A moderate delay (5-15mins) in collection of samples would lead to the assumed 'awakening' sample being collected during the 'time lag period' when cortisol levels are relatively stable (i.e. no dynamic increase during this time). The over-estimated CAR magnitude found in Study 1 would be a consequence of the real-time CAR-assessment period being shifted just sufficiently along the time axis to maximise the average level of cortisol measured in subsequent samples relative to the first sample but not being shifted sufficiently for that average to be influenced unduly by significantly lower post-peak values (unlike for longer delays > 15 min). The peak of cortisol peak would occur up to 15 min earlier than if the first sample was actually collected at the moment of awakening, which explains why the timing of the peak is earlier.

In summary, studies typically investigate the CAR in saliva samples collected at 15 min intervals with the assumption that cortisol rises linearly between sample points; however to the knowledge of the author this assumption has not been investigated directly. Smaller intervals between post-awakening saliva samples is required to explore directly whether there is a predicted time lag between awakening and the post-awakening rise in cortisol secretion.

Aims:

In order to understand the findings of Study I (results 2) that moderate delays impact on the CAR, the current study explored directly whether there was a predicted 'time lag' between awakening and the post-awakening rise in salivary cortisol secretion in an intensive study utilizing five min intervals between post-awakening samples.

Method:

Researchers or participants (N=10) familiar with the saliva sampling protocol collected saliva samples on two days (3 participants only on 1 day). Samples were collected on awakening and every 5 minutes for the first 45 minutes post-awakening and at 60 minutes post-awakening. As well as the self-report method, awakening and saliva sampling times were monitored electronically, (same devices used in study I).

Results:

There were no significant increases in cortisol levels before the 15 min point following awakening. Thereafter, cortisol levels were significantly higher than at awakening (see Figure 3).

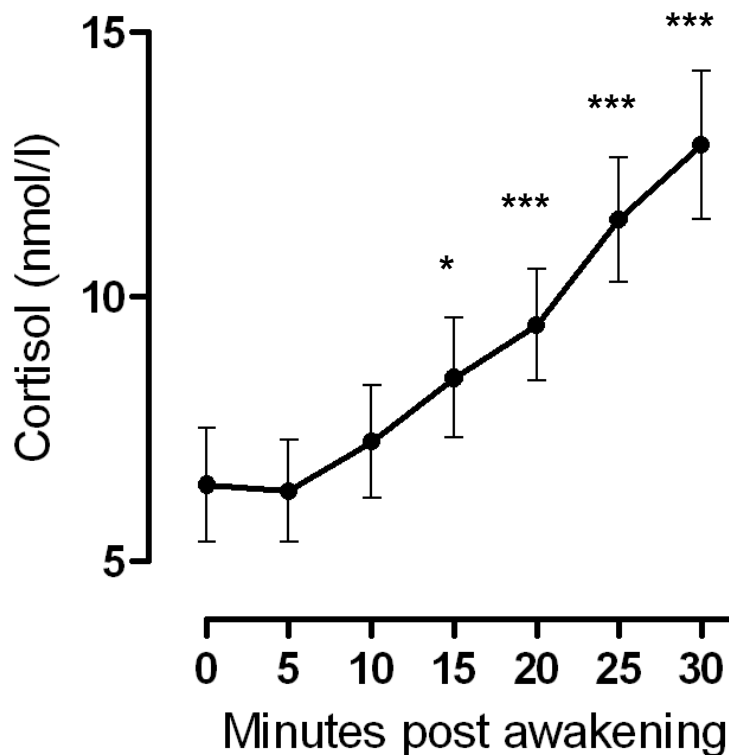


Figure 6 Cortisol samples 0 to 30 minutes post-awakening derived from study 2 * $p < .05$ *** $p < .001$ (S1 to subsequent sample specified axis)

Implications/Conclusions

In this study the 'time lag' hypothesis was tested in a small but intensive study of laboratory research personnel that were monitored for adherence and volunteered to collect saliva samples at 5 minutes intervals for the first 30 minutes post-awakening. As predicted there was no significant change in cortisol from awakening until the 15 minutes post-awakening point. This provides further support to the theoretical

explanation for the observed effects in study I (experiment I). The novelty of this study is the examination of the cortisol in the immediate period following awakening (i.e. 15 min). The previous assumption that cortisol increased in a linear manner was not supported by the findings of this study, rather there is a 10 minute lag between awakening and rise in cortisol secretion.

Study 3: Well-being, aging and cortisol secretion

Background

In Study 1 cortisol patterns were not associated with well-being, ill-being or attachment style. These null findings were attributed to the age of the participant. To explore this directly we compared relationship between hair cortisol and well-being/ill-being in young and older individuals. Measurement of cortisol in hair provides an alternative method of examining relationships with well-being/ill-being. Although salivary cortisol enables examination of the diurnal pattern of cortisol, it is limited by participant non-adherence to protocol, this is costly and time consuming to measure objectively using electronic estimates. Hair cortisol however, provides a retrospective trait measure of cortisol secretion. This enabled studying associations between cortisol and well-being/ill-being in a larger sample and comparison of young and old females without the issue of participant non-adherence.

Method:

The participants of the study were females drawn from two age groups: (1) younger adults, aged 18 to 26 years; (2) older adults, aged over 65 years. A sample of hair (at least 3 cm) from the posterior region of the scalp was collected. Participants completed demographic and hair characteristics questions and validated questionnaires of trait well-being/ill-being.

Results:

No relationship with hair cortisol and well-being or ill-being were evident in the group of young females. Whilst for the older group, higher levels of well-being were associated with higher hair cortisol concentrations (HCC), but no association for ill-being and HCC was found. The relationship found between HCC and well-being was independent of ill-being suggesting that well-being has a unique relationship with cortisol in the older age group.

Implications/Conclusions:

The finding that well-being is associated with HCC only in older individuals suggests that the effects of well-being are not exerted until later in life in healthy individuals. This provides support for the neurotoxicity hypothesis. The finding that ill-being is not related with HCC in these older females suggests that the effects of well-being are a stronger predictor of cortisol activity than ill-being. However, we also need to consider that in vulnerable individuals dysfunction of the HPA-axis may precede and predict later psychopathology (e.g. ill-being, low well-being aberrant cortisol profiles). Measures of vulnerability (such as attachment style and life events) may tease out vulnerable individuals and different associations between ill-being or well-being and cortisol measures may be observed to those reported here.

In this sample of healthy females it is possible that higher cortisol secretion is indicative of being busier and energized. Evidence for cortisol as an energiser is suggestive from studies showing that hypocortisolism is associated with pathologies characterized by exhaustion and fatigue in clinical and healthy populations (Adam, Hawkley, Kudielka, & Cacioppo, 2006; Crofford et al., 2004; Demitrack, et al., 1991; Kumari et al., 2009). Evidence for cortisol acting as an energiser in normal healthy populations comes from the finding that a more responsive HPA axis in terms of higher cortisol levels was associated with better physical functioning in older males (Gardner et al., 2011). Thus findings indicate that higher cortisol levels in normal a healthy older sample may be indicative of a healthier HPA axis.

Higher well-being was restorative of cortisol levels in older females. This is consistent with previous studies showing that in females higher cortisol is associated with positive affect (Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2005) and green space (Roe et al., unpublished). Thus in this sample of older healthy females well-being was associated with healthy cortisol levels in terms of having higher levels of cortisol which may be characteristic of being highly functioning, outgoing and busy and the finding that ill-being was not associated with HCC suggests that the females in this study were well balanced and not at risk of cortisol pathologies.

References

- Abercrombie, H. C., Giese-Davis, J., Sephton, S., Epel, E. S., Turner-Cobb, J. M., & Spiegel, D. (2004). Flattened cortisol rhythms in metastatic breast cancer patients. [Clinical Trial Controlled Clinical Trial Research Support, Non-U.S. Gov't Research Support, U.S. Gov't, P.H.S.]. *Psychoneuroendocrinology*, *29*(8), 1082-1092.
- Adam, E. K., Hawkley, L. C., Kudielka, B. M., & Cacioppo, J. T. (2006). Day-to-day dynamics of experience-cortisol associations in a population-based sample of older adults. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(45), 17058-17063.
- Broderick, J. E., Arnold, D., Kudielka, B. M., & Kirschbaum, C. (2004). Salivary cortisol sampling compliance: comparison of patients and healthy volunteers. *Psychoneuroendocrinology*, *29*(5), 636-650.
- Chida, Y., & Steptoe, A. (2009). Cortisol awakening response and psychosocial factors: A systematic review and meta-analysis. [Review]. *Biological Psychology*, *80*(3), 265-278.
- Crawford, J. R., & Henry, J. D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, *43*(3), 245-265.
- Crofford, L. J., Young, E. A., Engleberg, N. C., Korszun, A., Brucksch, C. B., McClure, L. A., . . . Demitrack, M. A. (2004). Basal circadian and pulsatile ACTH and cortisol secretion in patients with fibromyalgia and/or chronic fatigue syndrome. *Brain Behavior and Immunity*, *18*(4), 314-325.
- Demitrack, M. A., Dale, J. K., Straus, S. E., Laue, L., Listwak, S. J., Kruesi, M. J. P., . . . Gold, P. W. (1991). Evidence for impaired activation of the hypothalamic-pituitary-adrenal axis in patients with chronic fatigue syndrome. *Journal of Clinical Endocrinology and Metabolism*, *73*(6), 1224-1234.
- DeSantis, A. S., Adam, E. K., Mendelsohn, K. A., & Doane, L. D. (2010). Concordance between self-reported and objective wakeup times in ambulatory salivary cortisol research. *International Journal of Behavioral Medicine*, *17*(1), 74-78.
- Dockray, S., Bhattacharyya, M. R., Molloy, G. J., & Steptoe, A. (2008). The cortisol awakening response in relation to objective and subjective measures of waking in the morning. *Psychoneuroendocrinology*, *33*(1), 77-82.
- Dockray, S., & Steptoe, A. (2010). Positive affect and psychobiological processes. *Neuroscience & Biobehavioral Reviews*, *35*(1), 69-75.
- Evans, P., Clow, A., Hucklebridge, F., & Loveday, C. (2012). The cortisol awakening response is related to executive function in older age. *International Journal of Psychophysiology*.
- Gardner, M. P., Lightman, S. L., Gallacher, J., Hardy, R., Kuh, D., Ebrahim, S., . . . Ben-Shlomo, Y. (2011). Diurnal cortisol patterns are associated with physical performance in the Caerphilly Prospective Study. *International journal of epidemiology*, *40*(6), 1693-1702.
- Griefahn, B., & Robens, S. (2011). Cortisol awakening response--Sampling delays of 15 minutes are not acceptable. *International Journal of Psychophysiology*, *82*, 202-205.

- Hellhammer, J., Fries, E., Schweisthal, O. W., Schlotz, W., Stone, A. A., & Hagemann, D. (2007). Several daily measurements are necessary to reliably assess the cortisol rise after awakening: state and trait components. *Psychoneuroendocrinology*, *32*(1), 80-86.
- Holsboer, F. (2000). The corticosteroid receptor hypothesis of depression. *Neuropsychopharmacology*, *23*(5), 477-501.
- Huber, T. J., Issa, K., Schik, G., & Wolf, O. T. (2006). The cortisol awakening response is blunted in psychotherapy inpatients suffering from depression. *Psychoneuroendocrinology*, *31*(7), 900-904.
- Jacobs, N., Nicolson, N. A., Derom, C., Delespaul, P., van Os, J., & Myin-Germeys, I. (2005). Electronic monitoring of salivary cortisol sampling compliance in daily life. *Life sciences*, *76*(21), 2431-2443.
- Kashdan, T. B., Biswas-Diener, R., & King, L. A. (2008). Reconsidering happiness: The costs of distinguishing between hedonics and eudaimonia. *The Journal of Positive Psychology*, *3*(4), 219-233.
- Keyes, C. L. M., & Annas, J. (2009). Feeling good and functioning well: Distinctive concepts in ancient philosophy and contemporary science. *The Journal of Positive Psychology*, *4*(3), 197-201.
- King, L. A., & Napa, C. K. (1998). What makes a life good? *Journal of Personality and Social Psychology*, *75*(1), 156-165.
- Kudielka, B. M., Broderick, J. E., & Kirschbaum, C. (2003). Compliance with saliva sampling protocols: Electronic monitoring reveals invalid cortisol daytime profiles in noncompliant subjects. *Psychosomatic Medicine*, *65*(2), 313-319.
- Kumari, M., Badrick, E., Chandola, T., Adam, E. K., Stafford, M., Marmot, M. G., . . . Kivimaki, M. (2009). Cortisol secretion and fatigue: Associations in a community based cohort. *Psychoneuroendocrinology*, *34*(10), 1476-1485.
- Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. [Review]. *Nature Reviews Neuroscience*, *10*(6), 434-445.
- McEwen, B. (1998). Protective and damaging effects of stress mediators. *New England Journal of Medicine*, *338*(3), 171.
- Okun, M. L., Krafty, R. T., Buysse, D. J., Monk, T. H., Reynolds III, C. F., Begley, A., & Hall, M. (2010). What constitutes too long of a delay? Determining the cortisol awakening response (CAR) using self-report and PSG-assessed wake time. *Psychoneuroendocrinology*, *35*(3), 460-468.
- Oskis, A., Loveday, C., Hucklebridge, F., Thorn, L., & Clow, A. (2009). Diurnal patterns of salivary cortisol across the adolescent period in healthy females. *Psychoneuroendocrinology*, *34*(3), 307-316.
- Polk, D. E., Cohen, S., Doyle, W. J., Skoner, D. P., & Kirschbaum, C. (2005). State and trait affect as predictors of salivary cortisol in healthy adults. *Psychoneuroendocrinology*, *30*(3), 261-272.
- Pressman, S. D., & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin*, *131*(6), 925-971.
- Pruessner, J., Wolf, O., Hellhammer, D., Buske-Kirschbaum, A., Von Auer, K., Jobst, S., . . . Kirschbaum, C. (1997). Free cortisol levels after awakening: a reliable biological marker for the assessment of adrenocortical activity. *Life sciences*, *61*(26), 2539-2549.
- Ryff, C. D., Singer, B. H., & Love, G. D. (2004). Positive health: connecting well-being with biology. *Philosophical Transactions of the Royal Society B-Biological Sciences*, *359*(1449), 1383-1394.

- Schulz, P., Kirschbaum, C., Pruessner, J., & Hellhammer, D. (1998). Increased free cortisol secretion after awakening in chronically stressed individuals due to work overload. *Stress Medicine, 14*(2), 91-97.
- Sephton, S. E., & Spiegel, D. (2003). Circadian disruption in cancer: a neuroendocrine-immune pathway from stress to disease? *Brain Behavior and Immunity, 17*(5), 321-328.
- Stephoe, A., Gibson, E. L., Hamer, M., & Wardle, J. (2007). Neuroendocrine and cardiovascular correlates of positive affect measured by ecological momentary assessment and by questionnaire. *Psychoneuroendocrinology, 32*(1), 56-64.