The Role of Awakening Cortisol and Psychological Distress in Diurnal Variations in Affect: A Day Reconstruction Study

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People often feel unhappy in the morning but better later in the day, and this pattern may be amplified in the distressed. Past work suggests that one function of cortisol is to energize people in the morning. In a study of 174 students, we tested to see whether daily affect patterns, psychological distress, and awakening cortisol levels were interlinked. Affect levels were assessed using the Day Reconstruction Method and psychological distress was measured using the Depression Anxiety Stress Scales. On average, positive affect increased markedly in a linear pattern across the day, whereas negative affect decreased linearly. For the highly distressed, this pattern was stronger for positive affect. Lower than average morning cortisol, as assessed by two saliva samples at waking and two samples 30 min after waking, predicted a clear increasing pattern of positive affect throughout the day. When we examined the interlinkages between affect patterns, distress, and cortisol, our results showed that a pronounced linear increase in positive affect from morning through to evening occurred chiefly among distressed people with below average cortisol levels upon awakening. Psychological distress, although not strongly associated with morning cortisol levels, does appear to interact with cortisol levels to profoundly influence affect.

Keywords: cortisol, psychological distress, positive affect, diurnal variation, day reconstruction method

For some people, the morning alarm clock invokes feelings of enthusiasm, but for others feelings of apathy in the morning are commonplace. Distressed people and people with an evening preference often experience low positive affect in the morning relative to the evening (Peeters, Berkof, Delespaul, Rottenberg, & Nicolson, 2006; Jankowski & Ciarkowska, 2008). Prior research suggests a potential biological basis for morning affect patterns in cortisol, a major glucocorticoid hormone, which among other things functions to mobilize energy resources (Boksem & Tops, 2009). In this study, we predicted that deficient morning cortisol levels may, at least partially, explain low positive affect levels in the morning relative to the evening and why distressed people often do not feel energized toward a positive start to the day.

Diurnal Variation of Affect

Numerous studies have found positive affect to rise substantially throughout the day, whereas negative affect has not yet demonstrated a robust diurnal pattern (Clark, Watson, & Leeka, 1989; Egloff, Tausch, Kohlmann, & Krohne, 1995; Hall, Spear, & Stirland, 1964; Murray, 2007; Stone et al., 2006). This change in positive affect over the course of a single day has been proposed to be best represented by several models including a quadratic waveform (e.g., Murray, 2007), a bimodal pattern (Stone et al., 2006), and a linear relationship (Egloff et al., 1995). Although environmental factors appear to impact substantially on diurnal affect patterns (e.g., Stone et al., 2006), certain groups consistently experience more pronounced trends in affect than others, and this may have a biological basis. For example, there is particularly strong evidence that the affect levels of people with depression improve substantially throughout the day (e.g., von Zerssen et al., 1985; Peeters et al., 2006). Not only do depressed people often feel worse in the morning, they also tend to dislike the early hours of the day, regarding themselves as evening types (Hirata et al., 2007; Hidalgo et al., 2009). This morning-worse pattern is characterized by poor concentration and low positive affect in the morning that transitions into greater alertness and more intense positive feelings later in the day (e.g., after 5 p.m.) (Jankowski & Ciarkowska, 2008).

It has been suggested that such circadian rhythms are blunted in various forms of distress and in evening types, particularly rhythms that are regulated by brainstem and hypothalamic areas.
(Schulz & Lund, 1983; Wirz-Justice, 2008). Early morning hypo-
activity of the hypothalamus–pituitary–adrenal axis as indexed by
the diminished release of cortisol may therefore be an important
candidate for explaining a morning-worsening pattern of affect
(Fries, Hesse, Hellhammer, & Hellhammer, 2005). More precisely,
if cortisol can cause an increase in feelings of energy and reinvig-
orate fatigued people (e.g., Tops, van Peer, Wijers, & Korf, 2006;
Tops, Riese, Oldenhinkel, Rijssijik, & Ormel, 2008), then large
individual differences in the volume of cortisol upon awakening
may invoke divergent patterns of affect in the initial part of the
day.

Cortisol and Diurnal Variation in Affect

The diurnal pattern of cortisol release is a well-documented
biological process with an established circadian component. Cor-
tisol declines steeply throughout the day and is then regener-
dated during sleep, so waking levels are raised substantially and then
increase further, by 40% to 75% in the next half hour, to a daily
peak (de Weerth & Buitema, 2005). The cortisol awakening
response is assessed primarily with two metrics: the increase in
cortisol from waking and the total integrated volume of cortisol
released in the period immediately after waking (e.g., Chida & Steptoe,
2009; Pruessner, Kirschbaum, Meinlschmid, & Hellham-
mer, 2003). The former, cortisol increase from waking, has been
well examined and is thought to be a distinct component of the
cortisol cycle (e.g., Clow, Thorn, Evans, & Hucklebridge, 2004).
The awakening increase is responsive to psychosocial factors
potentially signaling the effect of anticipation of the upcoming
challenges of the day (e.g., Fries, Dettenborn, & Kirschbaum,
2009).

The less studied overall volume of awakening cortisol is closely
linked to the circadian cortisol cycle and does not appear to be
strongly related to psychosocial factors (e.g., Chida & Steptoe,
2009). The total volume of cortisol released over the waking
period may be relatively unaffected by psychosocial factors but yet
interact with such factors to explain morning affect levels. For
instance, for some people, with high levels of psychosocial re-
sources, low levels of morning cortisol may have little impact on
their affect levels. In contrast, low morning cortisol levels may act
to compound the already lethargic and negative state of the dis-
tressed.

Several recent studies show partial support for this idea. Healthy
people with a morning preference have been shown to have higher
cortisol levels in the first hour after waking than evening types
(Kudielka, Federenko, Hellhammer, & Wust, 2006; Kudielka,
Bellingrath, & Hellhammer, 2007; Bailey & Heitkemper, 1991). In
other research, people with diminished wake-up cortisol levels have
been shown to experience fatigue at waking and later in the day
(Dahlgren, Kecklund, Theorell, & Akerstedt, 2009; Adam, Hawk-
ley, Kudielka, & Cacioppo, 2006). Further evidence suggests that
the effects of reduced morning cortisol levels may be most pro-
ounced in the distressed. For instance, cortisol levels over the
wake-up period have been shown to be reduced in people with
chronic fatigue and burnout (Fries et al., 2005), those with post-
traumatic stress disorders (Chida & Steptoe, 2009; Rohleder, Jok-
simovic, Wolf, & Kirschbaum, 2004), people with mild to mod-
erate depression (Bhattacharyya, Molloy, & Steptoe, 2008), major
depression (e.g., Posener et al., 2000), and in anxious people and
suicide attemptors (Sjogren, Leanderson, & Kristenson, 2006;
Lindqvist, Isaksson, Traskman-Bendz, & Brundin, 2008).

The Present Investigation

In the present study, we therefore assessed people’s psychological
distress using the Depression Anxiety Stress Scales (DASS-
21) (Brown, Chorpita, Korotitsch, & Barlow, 1997; Antony, Biel-
ing, Cox, Enns, & Swinson, 1998). We also measured the total
volume of cortisol each person released over the waking period on
a work day (e.g., Pruessner et al., 2003), and we comprehensively
assessed affect and activity patterns throughout the same day using
the Day Reconstruction Method (Kahneman, Krueger, Schkade,
Schwarz, & Stone, 2004). Using multilevel regression, we first
sought to identify how best to model the temporal relation between
time of day and affect (e.g., linear, quadratic, cubic). Next, we
investigated whether higher levels of psychological distress would
modify the link between time of day and affect so as that the more
distressed experience a steeper increase in positive affect during
the day than those with lower distress scores. Although existing
research does not appear to generate robust predictions regarding
diurnal patterns of negative affect, we tested to see whether it
followed the opposite trend to positive affect (i.e., increased in the
morning among the distressed with a subsequent decrease).

We next examined the possibility that cortisol levels in the first
half hour after waking may predict the relationship between time
of day and affect. We expected that those with lower cortisol levels
in the first half hour from waking would show a greater increase in
positive affect and potentially a larger decrease in negative affect
throughout the day than those with higher cortisol levels. Fi-
ally, we sought to link our two initial hypotheses by testing to
see whether people with higher psychological distress and
lower morning cortisol levels are particularly likely to experi-
ence a pattern of increasing positive affect and decreasing
negative affect over the course of the day.

Methods

Participants

One hundred seventy-four (59 males, 115 females) students
participated in the study for course credit or 25 euro. The partic-
ipants ranged in age from 18 to 49 (M = 23, SD = 5.7), and 10%
of the sample indicated they had a chronic medical condition. On
the first day of the study, participants received verbal and written
instructions detailing what the study entailed and provided in-
formed consent. They then completed baseline physiological tests
administered by trained research nurses and received instruction
detailing the cortisol sampling procedure. On the next day, partic-
ips provided cortisol samples at waking and 30 min after
waking. Cortisol samples were examined solely on work days be-
cause morning cortisol levels have been shown to be systemati-
cally more pronounced on work days than at the weekend (e.g.,
Kunz-Ebrecht, Kirschbaum, Marmot & Steptoe, 2004). On the
third day of the study, the participants completed a day reconstruc-
tion survey (Kahneman et al., 2004), a measure of psychological
distress, and a series of questions about their health behavior.
Measures

Online day reconstruction. On the day after providing the saliva samples, participants completed a computer-assisted reconstruction of the objective details and affective experiences of the previous day. As in the original pen-and-paper day reconstruction survey (Kahneman et al., 2004), the online day reconstruction survey follows a fixed format to reduce recall bias. Participants first complete a diary by breaking their day into morning, afternoon, and evening stages and then recalling and labeling each episode from their day. Participants are instructed to consider their day as a film and episodes as scenes from that film, with the transition to each new episode representing a significant change (e.g., change of place, activity) and with each episode typically lasting between 20 min and 2 hr (Stone et al., 2006).

Because both cortisol and affect patterns can be affected by environmental factors such as one’s location (e.g., home, at work), activities (e.g., commuting, exercising), and social interactions, participants provided specific information about each of these factors during each episode reported. For each episode, participants also rated how much they felt positive affect (happy, calm, comfortable, affectionate, interested, confident) and negative affect (impatient, depressed, stressed, irritated) on a scale from 0 (not at all) to 6 (very much). Previous research suggests that the affect levels identified using the day reconstruction method appear to approximate those assessed using experience sampling (Kahneman et al., 2004; Dockray, Grant, Stone, Kahneman, Wardle, & Steptoe, 2010). Average levels of positive ($M = 3.6$, $SD = 1.1$) and negative ($M = 1.4$, $SD = 1.2$) affect were then converted to standardized $Z$ scores for the subsequent regression analyses. As is typical, positive and negative affect scores were found to be related ($r = -0.5$, $p < .001$) but sufficiently separable to be considered distinguishable.

Psychological distress. Psychological distress was assessed using the short-form version of the Depression Anxiety Stress Scales (DASS-21) (Brown et al., 1997; Antony et al., 1998), a brief 21-item instrument which has been shown to yield a general factor dimension representing psychological distress (Henry & Crawford, 2005). The DASS-21 is composed of three 7-item self-report scales from the extended version of the DASS. Each item refers to a particular symptom, and participants rate the extent to which the symptoms applied to them in the past week on a scale from 0 (did not apply) to 3 (applied to me very much or most of the time). Possible scores on the DASS-21 range from 0 to 63. In the present study, two participants were found to score over 50 and were considered statistical outliers and not included in subsequent analyses. The DASS-21 scores of the remaining participants ranged from 0 to 42 ($M = 14.4$, $SD = 9.6$).

Health and health behavior. An array of baseline health variables and health behaviors were assessed primarily to ensure that the cortisol analyses were not confounded by individual differences in health behavior, or consumption, which have been shown to influence diurnal cortisol cycles and/or affect levels. For instance, previous research has linked a high body mass index ($M = 23$ kg/m², $SD = 3.3$), body fat ($M = 29\%$, $SD = 8.2$), lung capacity ($M = 402.1$ L/min, $SD = 117$), and systolic ($M = 121$ mm Hg, $SD = 13.5$) and diastolic ($M = 68.2$ mm Hg, $SD = 9.4$) blood pressure. In addition, as part of the questionnaire component of the study, the participants responded to items related to their health behavior. Participants rated how often they exercise (from 0 = Never to 4 = 4 or more times a month) ($M = 3.31$, $SD = 1.29$). Twelve percent of the sample indicated they were current smokers, and 9% were currently on a diet. The frequency of alcohol consumption was rated on scale from 0 (Never) to 5 (4 or more times a week) ($M = 3.31$, $SD = 1.29$). Finally, we inquired as to whether the participants consumed alcohol on the day before the monitoring day (25% drank alcohol) and also if they drank during the monitoring day (24% drank alcohol).

Salivary cortisol sampling. A total of four salivary cortisol samples were collected from each participant using a Salivette collection device (Sarstedt, 51582 Numbrecht, Germany). Two samples were taken immediately at waking and then two samples 30 min after waking. The participants received detailed verbal instruction as well as a written protocol relating how to collect the saliva samples. Participants were requested not to eat, drink beverages, smoke, or brush/floss their teeth during the 30-min period from waking to when they had collected their fourth sample.

Participants completed an adherence monitoring form upon which they detailed the scheduled times when their samples were to be collected and the actual time each sample was provided. Six participants indicated that they collected one or more of their samples at times greater than 10 min from when scheduled and were thus not included in the final sample for this study (i.e., $N = 174$). The samples were returned to the laboratory the day after collection and frozen at $-80°$ C and subsequently assayed. The two samples at waking yielded highly consistent results ($r = .93$, $p < .001$) as did the later two samples at 30 min postwaking ($r = .91$, $p < .001$). We converted awakening and 30-min cortisol levels using log transformation to reduce skewness as is typical. The total integrated volume of cortisol over the awakening period was calculated as the total area under the curve (relative to zero) between the waking and 30-min postwaking samples (e.g., Pruessner et al., 2003; Chida & Steptoe, 2009).

Statistical Analysis

There were 1886 episodes reported in total (on average 10.77 per person) in the day reconstruction survey. To assist in the interpretation and presentation of the results, we focused on episodes for which the temporal midpoint of their duration was between 8 a.m. and 12 p.m. (1821 episodes). We applied multilevel analyses to examine most of the study questions. Multilevel analysis was particularly suited to the nested structure of the data in the current study and the uneven number of repeated assessments at the episode level (Stone et al., 2006). In this study, we had two levels of nesting: the episode level at which the affect and other day reconstruction data (e.g., location and activity information) was recorded (Level 1) and the person level at which the demographic, health and health behavior, psychological distress, and cortisol metrics were assessed (Level 2).
We first aimed to identify whether the relation between time of day and affect levels that produced the best fit was linear, quadratic, or cubic. Then, we aimed to examine the extent to which the temporal patterning of affect was linked to (i) psychological distress, (ii) awakening cortisol levels, and (iii) the interaction between distress and cortisol levels. To graphically examine these relations, we separated the sample into those with above or below average psychological distress levels and those with cortisol levels that were above/below the mean. To test for differences in the diurnal pattern of affect between these groups, we examined the slope of the affect levels and the associated confidence interval for each group.

**Results**

We first produced an unadjusted multilevel regression model testing the link between time of day, time-squared and time-cubed, and affect levels. Time of day was linearly linked to positive affect levels ($t = 6.67, p < .005; R^2 = .0203$). Incorporating time-squared or time-cubed into the model failed to substantially increase the variance explained by the model ($t^2 = .0204$; time$^3: R^2 = .0223$). Negative affect demonstrated a linear decrease over the course of the day ($t = -4.13, p < .005; R^2 = .008$). The inclusion of time-squared or time-cubed into the model produced a small increase in the variance in negative affect levels explained by the model ($t^2: R^2 = .0098$; time$^3: R^2 = .0102$). Overall, a linear model appeared to produce the best fit of the relationship between time of day and affect levels in the current data. We therefore examined the linear models linking time of day with positive and negative affect and how psychological distress and morning cortisol levels modify these linkages. The control variables included were activity patterns, social interactions, and location details at the episode level as well as demographic factors, baseline health, and health behavior variables at the level of the individual. Age and father’s education were largely unrelated to affect. Females were found to experience more positive affect than males, as shown in Table 1. In line with previous studies (e.g., Stone et al., 2006), positive affect increased across the course of the day, whereas negative affect declined markedly. Distressed participants experienced high levels of negative affect and low positive affect, as anticipated. Morning cortisol levels were not significantly related to distress. A positive affect levels of those with high distress $[-.005, r = .013]$ overlapped substantially, indicating that the two slopes were not different.

In additional analyses, we showed that morning cortisol levels and psychological distress were unrelated ($r = -0.04, p = .56$).

After this, we tested the three interaction effects that corresponded to the main hypotheses of the study. Demographic variables and control variables were included in each analysis as were lower order interaction effects for the three-way interaction analyses. First, we examined the relation between psychological distress and diurnal rhythms of affect. Participants with high levels of psychological distress were found to demonstrate a clear pattern of lower positive affect in the morning than the evening (i.e., psychological distress $\times$ time of day interaction), as shown in Table 2 and illustrated in Figure 1. Tests for the simple slopes suggested that the relationship between time of day and an increase in positive affect was stronger for those with above average psychological distress, ($B = .031, SE = .006, t = 5.31, p < .0005$) than for those with below average levels of distress, ($B = .011, SE = .004, t = 2.54, p < .05$). Confidence intervals for the simple slopes confirmed that the slope for positive affect across the course of the day was steeper for those with high psychological distress $[.031 \pm .012]$ than for participants with low psychological distress $[.011 \pm .008]$. The large differences in positive affect between distressed and nondistressed participants early in the day diminished as the day progressed and converged in the evening, as anticipated. Distress also interacted with time of day to predict negative affect. Distressed people showed a significant decrease in negative affect from morning through evening ($B = -0.14, SE = .007, t = -2.15, p < .05$), whereas the nondistressed did not ($B = -0.007, SE = .005, t = -1.43, p = .15$). However, the confidence intervals for the simple slopes of those with high distress [-.014 ± .013] and those with low distress [-.007 ± .01] overlapped substantially, indicating that the two slopes were not different.

Next, we tested to see whether people with low morning cortisol levels experience low positive and high negative affect levels in the morning relative to the evening (i.e., cortisol $\times$ time of day interaction). As expected, the positive affect levels of those with low morning cortisol were low in the morning and then subsequently converged with people with high morning cortisol in the evening, as shown in Table 2 and illustrated in Figure 2. More precisely, the relationship between time of day and positive affect was positive and highly significant for those with below average levels of morning cortisol ($B = .039, SE = .006, t = 6.03, p < .0005$) but nonsignificant for those with above average levels of morning cortisol ($B = .006, SE = .004, t = 1.48, p = .14$). Morning cortisol also interacted significantly with time of day to predict negative affect. Although the interaction effect identified was not easily interpretable from an inspection of the graph (Figure 2b), those with low morning cortisol levels did appear to experience a decrease in negative affect throughout the day ($B = -0.21, SE = .0066, t = -3.12, p < .005$), whereas those with high morning cortisol did not ($B = -0.05, SE = .005, t = -0.94, p = .35$). To summarize, the initial interaction analyses clearly showed that low levels of positive affect in the morning were predicted by both high psychological distress and low cortisol levels upon waking. There was also some tentative evidence

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Positive affect</th>
<th>Negative affect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>$-0.467 (0.54)$</td>
<td>$.87</td>
</tr>
<tr>
<td>Age</td>
<td>.005 (0.01)</td>
<td>$.6</td>
</tr>
<tr>
<td>Male$^a$</td>
<td>-.67 (1.19)</td>
<td>-3.46$^a$</td>
</tr>
<tr>
<td>Father’s education</td>
<td>-.037 (0.06)</td>
<td>-.62</td>
</tr>
<tr>
<td>Time of day (linear)</td>
<td>.021 (0.004)</td>
<td>5.49$^a$</td>
</tr>
<tr>
<td>Psychological distress</td>
<td>-.027 (0.005)</td>
<td>-5.27$^a$</td>
</tr>
<tr>
<td>Morning cortisol levels</td>
<td>.147 (0.08)</td>
<td>1.83</td>
</tr>
</tbody>
</table>

Note. Analyses are adjusted for activity patterns, social interaction, and location at Level 1 and health (body mass index, body fat, lung capacity, blood pressure) and health behavior (exercise, smoking, alcohol consumption, dieting) at Level 2.

$^a$ Female coded as 1, Male coded as 2.

$^{**} p < .01, ^{*} p < .05$. 

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that those with high psychological distress and low morning cortisol experience high negative affect in the mornings that diminishes as the day progresses.

Finally, we sought to show that the results from our initial two interaction effects were interlinked. More precisely, we expected that people with high psychological distress and low morning cortisol would experience the steepest increase in positive affect and potentially decrease in negative affect during the day (i.e., psychological distress × cortisol × time of day interaction). As expected, participants with above average levels of distress and with lower than average morning cortisol levels were the only group to experience a highly significant trend toward low positive affect early in the day followed by a sharp rise in positive affect (\(B = .052, SE = .009, t = 5.4, p < .0005\)) was more rapid than for those with above average distress alone (\(B = .031, SE = .006, t = 5.31, p < .0005\)) and marginally more rapid than for those with below average cortisol alone (\(B = .039, SE = .006, t = 6.03, p < .0005\)).

Those with both lower than average psychological distress and low morning cortisol were the only other group for which there was a statistically significant relationship between time of day and positive affect (\(B = .052, SE = .009, t = 5.4, p < .0005\)) was more rapid than for those with above average distress alone (\(B = .031, SE = .006, t = 5.31, p < .0005\)) and marginally more rapid than for those with below average cortisol alone (\(B = .039, SE = .006, t = 6.03, p < .0005\)).

Table 2

<table>
<thead>
<tr>
<th>Hypothesized interaction(^a)</th>
<th>Dependent variable</th>
<th>Positive affect (B (SE))</th>
<th>(t)</th>
<th>Negative affect (B (SE))</th>
<th>(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Psychological distress × time of day (linear)</td>
<td>(+.002 (.0004))</td>
<td>4.56***</td>
<td>(-.001 (.0004))</td>
<td>(-2.79^{**})</td>
<td></td>
</tr>
<tr>
<td>2. Morning cortisol × time of day (linear)</td>
<td>(-.0205 (.005))</td>
<td>(-3.74^{**})</td>
<td>(.02 (.006))</td>
<td>3.29***</td>
<td></td>
</tr>
<tr>
<td>3. Psychological distress × morning cortisol × time of day (linear)(^b)</td>
<td>(-.002 (.0006))</td>
<td>(-3.42^{**})</td>
<td>(.001 (.001))</td>
<td>1.15</td>
<td></td>
</tr>
</tbody>
</table>

\(a\) Analyses are adjusted for time of episode, social interaction, activity patterns, and location at Level 1 and psychological distress, morning cortisol levels, demographic factors (age, gender, father’s education), health (body mass index, body fat, lung capacity, blood pressure), and health behavior (exercise, smoking, alcohol consumption, dieting) at Level 2. \(b\) Analyses are adjusted for two-way interaction effects in addition to control variables.

\(**\) p < .01. \(***\) p < .005.

Figure 1. Standardized (a) positive and (b) negative affect as a function of time of day for participants with low and high psychological distress.
the day progresses and may even surpass the positive affect levels of distressed people with high morning cortisol by the evening. Nondistressed people with low morning cortisol did experience a rise in positive affect during the day, but this increase was smaller in magnitude than the increase in the low cortisol–high distress group. No such three-way interaction was identified for negative affect.

Discussion

The present results indicate that there are predictable patterns in diurnal rhythms of affect that can be explained by both psychological and biological factors. Consistent with previous reports, in the sample as a whole, we found that positive affect increased considerably throughout the day and negative affect declined slightly (Stone et al., 2006). However, although these patterns have been identified in healthy people and appear to be robust, average changes in affect may mask the effect of important individual differences that could explain emotional fluctuations.

Although it is clear that distressed people are likely to feel worse than the nondistressed throughout a given day, the diurnal trend in

![Figure 2.](image1.png)

![Figure 3.](image2.png)
the emotions of the distressed is perhaps less obvious. Using a measure of psychological distress composed of depression, anxiety, and stress scores, we showed that more distressed people experienced a clear trend toward low positive affect and to some extent high negative affect in the mornings relative to the evenings. It could therefore be the case that the diurnal changes in affect observed across numerous studies (e.g., Murray, 2007; Stone et al., 2006; Peeters et al., 2006) may be a direct result of large fluctuations in affect among certain groups such as the distressed. Moreover, previous observations of morning-worst affect in distressed people have lead commentators to suggest that such changes in affect may have a physiological basis grounded in systems that follow a circadian rhythm (Axelsson, Akerstedt, Kekuland, Lindqvist, & Attefors, 2003).

Cortisol, Affect Patterns, and Distress

The present study also found that morning cortisol was of crucial importance to affect levels early in the day. We analyzed the total cortisol output in the first half hour after waking, an important marker of neuroendocrine functioning (e.g., Chida & Steptoe, 2009; Pruessner et al., 2003). People with a below average level of cortisol output in the first half hour after waking had lower positive affect and higher negative affect in the morning, which improved substantially over the course of the day, converging with those with an above average volume of morning cortisol late in the evening. This result links well with earlier findings showing that people who prefer the morning to evening typically feel better during the initial hours after waking and have higher wakeup cortisol levels than those who prefer evenings (Jankowski & Ciarkowska, 2008; Bailey & Heitkemper, 1991; Kudielka et al., 2007). In addition, the strong association between low levels of awakening cortisol and diminished positive affect identified in the current study is consistent with research showing that groups with generally diminished energy (e.g., chronic fatigue, burnout) and low mood levels (e.g., posttraumatic stress, melancholic depression) tend to have reduced cortisol levels in the period after waking (Boksem & Tops, 2009). Furthermore, our analyses suggest that the divergent diurnal patterns of affect predicted by morning cortisol levels were unlikely to be explained by activity patterns, environmental changes, or baseline health or health behavior differences.

Perhaps most importantly, we found that psychological distress, morning cortisol, and affect patterns were interlinked. We showed a clear shift in positive affect from reduced morning levels to a much improved evening state among distressed people with below average cortisol levels in the period after waking. This finding draws together two parallel streams of research: the first demonstrating that distressed people are likely to experience a steeply increasing pattern of positive affect during the day (Murray, 2007; Peeters et al., 2006) and the second showing that reduced volumes of morning cortisol are linked to a dislike of the initial hours of the day (e.g., Kudielka et al., 2006) and to clinical conditions characterized by low energy and mood (e.g., Fries et al., 2005). We suggested that psychological distress, although not strongly associated with morning cortisol levels, may interact with cortisol levels to profoundly influence affect. In line with this idea, the distressed appear to be particularly vulnerable to a physiological susceptibility to low positive affect early in the day, as indexed by diminished awakening cortisol levels.

If the findings from the current study can be replicated, they will have several implications. For instance, distressed people who experience a marked evening improvement in mood on a daily basis may postpone seeking treatment, as has been noted to occur in morning-worse depression (Carpenter, Kupfer, & Frank, 1986). It is possible that the exogenous administration of cortisol to those with deficient morning levels may stimulate an enhancement of positive mood (e.g., Tops et al., 2006) and reduce negative affect (e.g., Putman, Hermans, Koppeschaar, van Schijndel, & van Honk, 2007). The growing field of chronotherapeutics is likely to offer numerous nonpharmaceutical treatments to normalize disruptions in affective rhythms, such as light therapy and manipulations of the sleep-wake cycle (e.g., sleep deprivation), which may assist in normalizing the cortisol cycle (Wirz-Justice, 2006; Monteleone & Maj, 2009).

Limitations

Three central limitations of this study should be noted. First, the day reconstruction method protocol constrains the data collected in several ways. Participants are requested to only report episodes that are at least 20 min in length, meaning that more abrupt but potentially meaningful experiences may be omitted. The day reconstruction survey also restricts the reporting of activities, locations, and interactions to a nonexhaustive set of common response options. Furthermore, it is possible that experience sampling techniques for the ambulatory assessment of affect that permit the open-ended reporting of a wide array of activities and interactions may yield more high frequency and potentially more accurate results than the day reconstruction survey. However, because the day reconstruction survey is designed to be exogenous to the period under scrutiny and to minimize recall bias by carefully evoking contextual information, we believed it represented the optimal trade-off between respondent burden and ecological validity.

Second, because the survey reporting period was restricted to the participants’ chosen period of wakefulness, this meant that affect patterns across broader time horizons (e.g., 24 hr) were not examined. Incorporating a sleep deprivation protocol to test affect rhythms over lengthy time periods, although potentially less ecologically valid than naturalistic monitoring of the waking hours, may have assisted in identifying the curvilinear, quadratic, or cubic circadian rhythm in affect shown in previous studies (e.g., Murray, 2007; Peeters et al., 2006). Third, although we took measures to ensure compliance with the saliva sampling protocol, we relied on the accuracy of the participants self-reports, which may overestimate actual compliance (Broderick, Arnold, Kudielka, & Kirschbaum, 2004). Finally, it is unclear that the present data can be generalized to representative samples or indeed clinical conditions. For example, because the activity of the hypothalamus–pituitary–adrenal axis varies substantially over the life-course (e.g., Saxbe, 2008), the results of this study may not be generalizable to older adults. Also, groups such as hospitalized psychiatric patients may differ qualitatively in their affective and psychobiological functioning from healthy people with mild or moderate affective disturbances (Stetler & Miller, 2005).
Conclusions
Despite these limitations, the current data provide strong evidence linking several existing strands of research. We replicated research showing a morning-worse affect pattern to be a prominent feature of psychological distress. In addition, we found that people with higher morning cortisol levels tend to be happier in the morning than those with diminished waking cortisol levels. We extended this finding to psychological distress, showing that distress did not influence morning cortisol levels but instead interacted with cortisol output to predict positive affect. More precisely, distressed people with below average morning cortisol started off the day with especially diminished positive affect that subsequently increased quickly. Future research should examine how people respond to interventions that aim to modify the psychological and biological factors underlying diurnal rhythms of affect. This research will yield potentially critical insights into understanding everyday rhythms of affect in both healthy people and those with affective disorders.

References


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