A Population Approach to the Study of Emotion: Diurnal Rhythms of a Working Day Examined With the Day Reconstruction Method

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To date, diurnal rhythms of emotions have been studied with real-time data collection methods mostly in relatively small samples. The Day Reconstruction Method (DRM), a new survey instrument that reconstructs the emotions of a day, is examined as a method for enabling large-scale investigations of rhythms. Diurnal cycles were observed for 12 emotion adjectives in 909 women over a working day. Bimodal patterns with peaks at noon and evenings were detected for positive emotions; peaks in negative emotions were found at mid-morning and mid-afternoon. A V-shaped pattern was found for tired and an inverted U-shaped pattern for competent. Several diurnal patterns from prior studies were replicated. The DRM appears to be a useful tool for the study of emotions.

Keywords: affect, emotion, diurnal rhythm, DRM

Emotions are fundamental qualities of the human experience and they play a key role in understanding human health and behavior. Although there are many ways of measuring emotions, most studies have individuals self-report on how they are or were feeling over some specified period of time. A common assessment is the adjective checklist, wherein a set of emotion words (e.g., happy, sad) are presented with intensity response options such as *not at all*" through *very much*. Although some assessments target current emotions, others specify reporting periods ranging from the previous day to the previous month. Other assessments are intended to assess trait components of emotion; they ask about the respondent's usual emotions, without a specific recall period. Regardless of the assessment method, most research has focused on between-person differences in the levels of emotion, either in general or at particular points in time. The focus of this article is on a quality of affect that is often overlooked: its rhythmicity over the course of the day.

Conceptually, diurnal rhythms of affect are likely to be the product of both environmental influences and physiological processes. Both of these broad classes of determinants are themselves, in part, a function of the rhythm of daily life. For most people, activities of daily living are clearly entrained to the 24-hr clock and obvious effects on affect might be expected at different hours of the day, for example, comparisons between work and nonwork hours. Regular daily events such as commuting and consuming meals are also likely to be reliably associated with increased negative and positive affect, respectively (Kahneman, Krueger, Schkade, Schwarz & Stone, 2004). As for physiological influences, it is acknowledged that almost all biological processes have some diurnal cycle component (Smolensky & Dalonzo, 1993); for example, cortisol, a stress hormone, typically exhibits a steep decline throughout the day and is regenerated during sleep (Kirschbaum & Hellhammer, 1989). It may be the case that some emotions are particularly sensitive to the psychosocial environment or to particular components therein, whereas others are more influenced by physiological processes (Scherer, Wranik, Sangsue, Atran & Scherer, 2004; Stone, Smyth, Pickering & Schwartz, 1996). In addition to being caused by environmental and biological processes, diurnal cycles of affect may themselves affect behavior. The diurnal cycle of some negative affects (e.g., depression, anxiety, tiredness), for example, may be predictive of suicidal behavior or of the incidence of occupational accidents (Fortson, 2004). Conversely, the cycle of positive affects may predict optimal concentration and efficiency at work. As such, emotion cycles are an essential part of daily experience and may provide insights into daily behavior and symptoms.

From a methodological perspective, multiple assessments of immediate affect across the day (or days) are used to construct diurnal patterns, and greater numbers of assessments per day allow for the detection of finer-grained patterns. Recently, several stud-

ies of affect have been based on experience sampling or ecological momentary assessment methods (Stone & Shiffman, 1994; Stone, et al., 2000) wherein participants carry a paper or electronic diary with them throughout the day and complete it according to preset schedules. These methods have enabled the study of momentary variables like affect in the environments people typically inhabit, increasing the ecological validity of the measurements. Studies of immediate emotion are, however, highly burdensome for participants and costly for investigators, which partially explains why most studies of diurnal cycles are based on relatively small numbers of participants. Many studies have been conducted with fewer than 20 participants and many with just a few participants although often for longer periods of time.

In this report we present an alternative to real-time momentary assessment for assessing diurnal cycles of affect. The new method, called the Day Reconstruction Method (DRM; Kahneman et al., 2004), is based upon having participants recreate yesterday's activities and the affect associated with those activities using a questionnaire. Because the questionnaire takes about an hour to complete, it is feasible to design studies to examine activities and affect with large numbers of participants. This feature of the DRM opens the possibility of epidemiological studies of diurnal rhythms of affect and other daily experiences. In many ways, the DRM methods are similar to those used in time-budgeting surveys such as the American Time Use Survey (Horrigan & Herz, 2004) and food frequency surveys, because recall bias concerns led the developers of the instruments to limit recall to a single day. Data on the instrument were recently published (Kahneman et al., 2004), and the analyses presented here use the same data set to address a different research question.

The two goals of this article are (a) to demonstrate the feasibility of studying diurnal rhythms of specific affect adjectives with the DRM in a large sample and (b) to test several small-sample findings about diurnal rhythms of affect with a large sample of women who used the DRM for a single working day. Relying exclusively on work days has advantages and disadvantages. The work day for a typical individual includes regularly scheduled activities such as the morning commute, a morning segment of work, lunch, an afternoon segment of work, the afternoon commute, and a nonwork evening. Of course, these events do not occur at exactly the same time for all working people, but in a large sample of people there will certainly be a tendency for certain activities to occur during certain parts of the day (e.g., lunch around noon, commuting at the beginning and end of the day). If such activities are responsible for diurnal cycles of affect, then an advantage of studying work days is that a strong diurnal cycle should emerge for the group. A disadvantage of sole reliance on work days is that the hypothesized effects of activities will be confounded with effects hypothesized to be due to physiological processes. One strategy for teasing these effects apart would be study both work days and nonwork days, where the effects of activities on group cycles should be reduced. Unfortunately, only a few nonwork days were available in our sample and they have been eliminated from consideration in the analyses.

The feasibility goal of the article is addressed by determining if there are significant time-of-day (ToD) effects on participants' self-reports as assessed by the 12 emotion adjectives used, expanding upon the information presented in our prior publication on the DRM (Kahneman, et al., 2004). The article's second goal is addressed by exploring the following four previously documented ToD effects:

1. Several researchers found that energy levels and positive affect are highest in the morning (Wood, Magnello & Sharpe, 1992; Wood & Magnello, 1992). However, these studies sampled a limited number of times throughout the day (6 fixed points), yielding a relatively coarse degree of discrimination. In an attempt to replicate these results, we examine self-reports of Tired, conceptualized as the inverse of Vigor, and three positive emotions, captured by adjectives (Happy, Calm/Relaxed, and Enjoy). Because the DRM characterizes affect through the entire day (by breaking the day into discrete episodes), we were able to create much finer depictions of diurnal cycles.

2. Several investigators reported that positive, but not negative, emotions show diurnal cycles, although the evidence is mixed (Monk, Fookson, Moline, & Pollack, 1985). In part, the absence of diurnal effects in prior studies may be attributable to low statistical power due to small sample sizes (although recording across many days per individual, which some studies have done, increases power). Our sample is relatively large and should have ample power to detect diurnal cycles and moderators of cycles.

3. The impact of age on emotion has been a topic of considerable interest in recent years and a striking finding is that the elderly report higher levels of positive emotions (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000). Diurnal cycles of emotions have been examined in one study and were found to be independent of participants' age (McNeil, Stones, Kozma & Andres, 1994). The study of potential moderator variables such as age is especially well-suited to survey methods such as the DRM, given the large number of potential participants. In a previous report (Kahneman et al., 2004), we examined the diurnal cycles of Tired as a function of participants' age and found that age differences were limited to the morning hours. Young adults (under 30 years old) were significantly more tired in the morning than other participants, but this difference vanished over the course of the day. In this article we examine the impact of age on all 12 emotion adjectives.

4. The fourth specific test of diurnal rhythms is based on Adan's (Adan & Sanchez-Turet, 2001) finding that women's "optimal" emotional point throughout the day is around 11 a.m. This finding was based on a very limited sample (40 university student volunteers) aged between 18 and 23 years. We attempt to replicate the finding with our sample of working women by creating an emotional balance measure based on the difference between positive and negative emotions. This is conceptually similar to the rationale for the well-known Affect Balance Scale (Bradburn, 1969). The hypothesis was that its level would peak at around 11 a.m.

5. Finally, as we have implied above, any observed diurnal patterns in emotion reports are likely to be associated with, if not caused by, activities that occur on a regular basis during a working day. In fact, our prior research has shown that most diurnal cycles of mood are attenuated when the effects of concurrent activities are statistically removed. An exception to this statement was the observation that the daily pattern of tiredness, which did have a distinct diurnal cycle, was not diminished by removal of activities. We will test this activity hypothesis with a selection of mood adjectives.

Method

Participants

Participants were recruited by a professional survey firm in Texas, who randomly contacted potential participants with telephone calls. The firm selected 1,018 adult women by sampling from driver's license lists; by design, the recruitment strategy oversampled employed teachers, nurses, and telemarketers. Selection was limited to women in this first application of the DRM in order to reduce variability attributable to gender differences. The average age was 38 years, and the sample consisted of 24% Black, 22% Hispanic, 49% White and 5% other, with an average household income of $54,700 (slightly above average for the areas sampled). The mean education level was "some college." The 909 women who reported working on the day sampled were retained for these analyses.

Materials

The DRM was developed to allow for the assessment of activities and affect of the previous day with minimal recall bias. Respondents first construct a diary of the previous day, with the following instructions:

> Think of your day as a continuous series of scenes or episodes in a film. Give each episode a brief name that will help you remember it (e.g., "commuting to work" or "at lunch with B"). Write down the approximate times at which each episode began and ended. The episodes people identify usually last between 15 minutes and 2 hours. Indications of the end of an episode might be going to a different location, ending one activity and starting another, or a change in the people you are interacting with.

This task is completed on a confidential questionnaire, which respondents do not need to turn in. Next, respondents describe each of the specific episodes identified, including the starting and ending times, what they were doing (selected from a choice of 16 activities, arranged in order of rated average positive emotion: engaging in intimate relations, socializing, relaxing, praying/worshipping/meditating, eating, exercising, watching TV, shopping, preparing food, on the phone, napping, taking care of my children, using a computer/e-mail/Internet, doing housework, working, and commuting), with whom they were interacting (friends, relatives, spouse/ significant other, children, clients/customers, coworkers, boss, no one), and how they felt during the episode.

The 12 adjectives comprising the emotion assessment are listed in Table 1. The adjectives are very similar to those used in other mood adjective checklists such as the Nowlis (Nowlis, 1965), POMS (McNair, Lorr & Droppelman, 1972), and PANAS (Clark, Watson & Leeka, 1989; Watson & Tellegen, 1985), and, based on this previous research, 9 of the adjectives were used to index the constructs of Positive Affect (Happy, Warm/ Friendly, and Enjoying Myself) and Negative Affect (Frustrated/Annoyed, Worried/Anxious, Depressed/Blue, Hassled/Pushed Around, Criticized/Put Down, and Angry/Hostile). The remaining three adjectives (Impatient, Competent, and Tired) are considered individually. Response scales for the adjectives ranged from 0 (*not at all*) to 6 (*very much*), with the remaining points unlabeled. Other sections of the questionnaire asked respondents for demographic information, the qualities of their job, and other personal details; these questions are not used in this article.[1]

Procedures

Respondents came at a prearranged time to a central location (hotel ballrooms), where they filled out the questionnaire in large groups. Research staff directed the groups in the completion of the DRM. Respondents were paid $75 for their participation.

Analysis plan. Using traditional repeated measures analysis of variance techniques to analyze real-time data (or near real-time data) can be prob-

lematic (Affleck, Zautra, Tennen & Armeli, 1999; Schwartz & Stone, 1998; Schwartz & Stone, in press). Hierarchical linear modeling or multilevel modeling is generally preferable in that it allows for unequal numbers of repeated assessments, missing data, autocorrelation among repeated measures, and various error structures. We test for diurnal rhythms by including ToD variable as a categorical within-person predictor in this type of model.

In preparing the data for analysis, the issue arises as to how to represent the timing of DRM episodes, which are defined by beginning and end times. For the multilevel analysis, we used each episode's midpoint (the average of starting and ending times) to represent when the episode occurred. These midpoints were categorized into 15 one-hour blocks (e.g., 9:00–9:59 a.m.). Although this procedure ignores the duration of the episode, it has the advantage that the degrees of freedom for the inferential statistics are based, appropriately, on the number of episodes reported. However, in order to graphically display the diurnal rhythms of affect at a finer resolution, we constructed a data set in which each person's mood at 7:00 a.m. and every quarter-hour thereafter until 9:00 p.m. was stored. In this data set, the mood ratings of an individual episode were assigned to all of the 15-min time points that occurred within that episode. Averaging over all individuals for each time point creates a finer-grained profile of affect over the day than collapsing the episode midpoints into one-hour categories. In this graphical analysis, every person contributes to the average mood at a given time point, except if the person was asleep, either early in the morning or later at night. We note that this second data set could not be used to test for diurnal patterns (i.e., inferential analyses), because the number of observations far exceeds the number of episodes on which mood ratings were made.

Results

Responses to the DRM

The average number of episodes reported was 14.1 (*SD* = 4.8) and the median episode length was 61 min. There were no reported problems in the administration of the DRM.

Levels of Affect and Diurnal Cycles

The levels and variability (across all respondents and episodes) of affect as measured by the DRM are shown in Table 1, in the order in which the adjectives were presented in the questionnaire. Positive moods (Happy, Warm, Enjoy; the full adjective labels were presented above and we now use shorter versions for brevity) clearly have the highest levels of endorsement, whereas negative emotions (Frustrated, Depressed/Blue, Hassled, Angry, Criticized, Worry) have considerably lower levels. Figures 1 and 2 present plots for each mood where the mean level of the affect was computed at 15-min intervals. In order to show absolute levels of responses, while taking into account the higher levels of reporting for the positive adjectives, different *Y*-axes were used for Figure 1 and Figure 2.

Tests of Diurnal Cycles for Each Emotion

We first tested whether each emotion adjective was significantly associated with ToD. Results of the mixed model, where time was treated as a categorical variable, are shown in the fifth column of Table 1. All of the *F* tests were significant and the percentage of within-person variance that hour of the day accounted for was computed for each adjective (shown in column 6 of Table 1). The strongest diurnal patterns, accounting for more than 4% of the variance, were observed for Tired, Enjoy, Impatient, and Happy. However, Tired, was by far the adjective most strongly linked to

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[1] The full instrument is available at http://sitemaker.umich.edu/ norbert.schwarz/day_reconstruction_method.

Table 1

Descriptive Statistics and Results of Multilevel Analyses for Categorical and Linear Effects of Time-of-Day on Emotional Adjectives (n = 909)

	Average	SD	N of episodes	Mixed model test of categorical hour-of-day variable: F test (df)	% of Within-person variance accounted for by hour	Mixed model test of linear component of time-of-day:	
						F test	Beta
a. Impatient	1.99	2.20	11,656	37.5 (16, 8603)	5.2%	1.3ns	−.005
b. Happy	3.96	1.70	11,749	31.8 (16, 8670)	4.3%	404.4	.052
c. Frustrated	1.39	1.81	11,633	24.3 (16, 8583)	3.4%	220.7	−.045
d. Depressed/Blue	.65	1.37	11,615	3.1 (16, 8571)	0.3%	24.8	−.009
e. Competent	4.22	1.96	11,683	11.4 (16, 8586)	1.5%	28.4	−.013
f. Hassled	.60	1.33	11,627	13.7 (16, 8579)	1.9%	167.9	−.028
g. Warm	3.87	1.78	11,693	18.2 (16, 8628)	2.4%	52.6	.020
h. Angry	.53	1.24	11,613	7.3 (16, 8569)	0.9%	71.2	−.017
i. Worried	1.28	1.79	11,645	13.2 (16, 8594)	1.8%	164.7	−.034
j. Enjoy	3.65	1.96	11,713	38.5 (16, 8648)	5.2%	400.5	.063
k. Criticized	.24	.88	11,624	3.0 (16, 8580)	0.3%	4.2ns	−.003
l. Tired	2.75	2.17	11,709	154.6 (16, 8643)	18.5%	1473.4	.112

Note. F tests in Columns 5 and 7 are significant at the $p < .01$ level, except where noted with ns.

ToD: It shared 18% of the variance with ToD. The weakest diurnal patterns, accounting for less than 1% of the variance, were observed for Criticized, Depressed/Blue, and Angry, which also happen to be those with the lowest average levels.

On the basis of the multilevel analyses, standard errors were computed for testing the difference between points on each plot, and they were multiplied by 2 in order to approximate 95% confidence intervals. These values are presented in the captions for Figures 1 and 2; a difference of at least that amount between any two points in a plot is significant at the .05 alpha level. It is clear that many of the adjectives show a bimodal pattern with midday as the major inflection point. Apparently, lunch is a high point of the work day for many of these working women, associated with a drop in negative affect and a rise in positive affect. On the other hand, two of the adjectives have cycles that are not bimodal: Tired shows a V-shaped pattern and Competent an inverted-U shape pattern.

To address whether there were overall increases or decreases across the day, we examined the linear component of time for each adjective. ToD was treated as a continuous variable and the results of these analyses (F tests and regression coefficients) are shown in the last two columns of Table 1. The adjectives that were most strongly associated with categorically coded ToD also exhibited stronger linear associations with ToD. However, the F tests for Impatient and Criticized were not significant (though it was for Depressed/Blue). The sign of each regression coefficient indicates the directionality of the linear component of the association and, in general, positive feelings increase in magnitude over the day, whereas the negative feelings decrease. These linear trends must be viewed with some caution, given the nonlinear effects that were also evident in many of the diurnal patterns.

Tests of Specific Patterns of Diurnal Affect

1. Positive affect and tiredness during the morning versus evening. The hypothesis that affect and energy (viewed as the inverse of tiredness) were highest in the morning was tested by estimating the contrast in positive emotions (Happy, Warm, and Enjoy) and Tired for the morning hours of the day (7 a.m.–11 a.m.) versus the evening hours (5 p.m.–9 p.m.). All four contrasts were significant [Happy: $t(8670) = 17.51$, $p < .001$, difference$_{evening-morning}$ = .56; Warm: $t(8628) = 6.09$, $p < .001$, difference$_{evening-morning}$ = .20; Enjoy: $t(8648) = 16.0$, $p < .001$, difference$_{evening-morning}$ = .62; Tired: $t(8643) = 29.03$, $p < .001$,

difference$_{evening-morning}$ = 1.02]. Contrary to the previously cited studies, all tests were in the direction of evenings having higher levels of positive affect than mornings and higher levels of tiredness. In terms of effect size, the standard deviations of the momentary variables range from 1.7 to 2.2, so the change is at about 40% of a standard deviation for Tired and at least 25% for Happy and Enjoy, whereas the effect for Warm is much smaller. Inspection of Figure 2 shows that there is considerable variation within the hours defining morning and evening, but the contrasts demonstrate that, on average, the levels of positive affect and tiredness are greater in the evening than in the morning.

2. Positive, but not negative, affects have a diurnal cycle. Several earlier studies (Wood, et al., 1992) observed diurnal cycles for positive but not for negative emotions; others observed diurnal cycles for both (Monk et al., 1985). As shown in the first section of the Results section, significant diurnal cycles were observed for all emotion adjectives in the present data. However, there was considerable variation in the strength of these effects, with Tired showing the strongest ToD effect, followed by the positive affect adjectives of Happy, Warm, and Enjoy. Three adjectives were weakly associated with hour of the day: Depressed/Blue, Angry, and Criticized. Nevertheless, some of the negative affects had robust associations with hour, including Frustrated, Hassled, and Worried. Thus, we conclude that both positive and negative affects have diurnal cycles.

3. Age invariance of diurnal cycles. Earlier research (McNeil, et al., 1994) suggested that diurnal cycles are invariant across age, although Kahneman (Kahneman, et al., 2004) observed age differences in tiredness over the course of the day. To examine the relationship between diurnal cycles and age, the mixed model was expanded to include respondents' age, both its main effect and its interaction with hour-of-day (see Table 2). Age was coded as a continuous variable and hour remained a categorical variable so that all potential interaction patterns, and not only linear trends, would be tested. All three of the positive emotions were associated with significant interactions between ToD and age, in contrast to earlier findings (McNeil, et al., 1994). To examine the interaction patterns, least square means were computed substituting age equals 30 and 60 to create two profiles of affect (see Figure 3). For the positive affects, the interaction is attributable to younger people having less positive affect in the morning hours than older people. Fewer interactions were observed for the remaining emotions. For Worried, younger people had higher levels in the morning than older people. A similar pattern was observed for Tired where
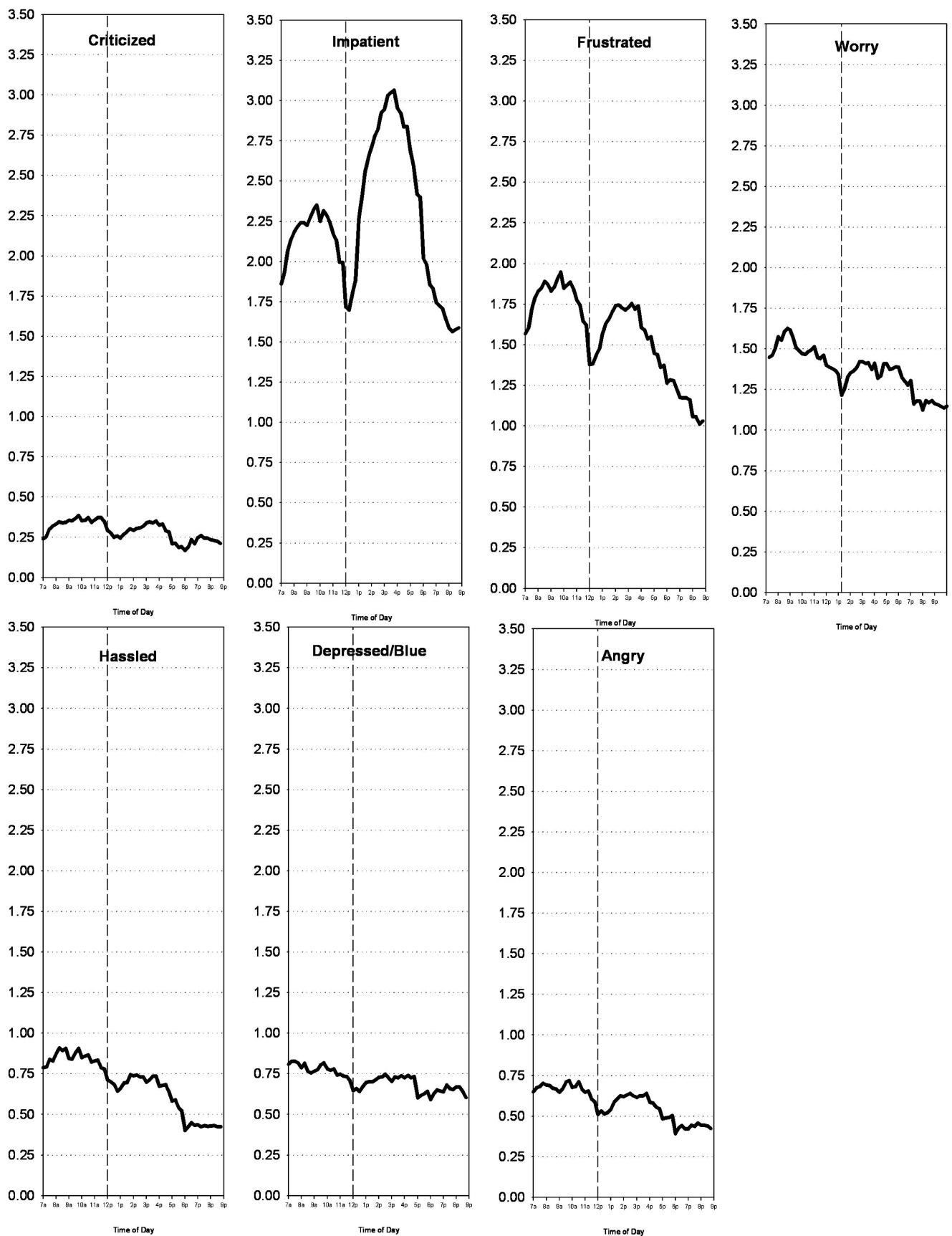
Figure 1. Diurnal cycles of negative emotion adjectives and Impatient. The difference between two points on a plot differ at the .05 alpha level when they differ by approximately .08 for Criticized, .22 for Impatient, .16 for Frustrated, .14 for Worried, .12 for Hassled, .10 for Depressed/Blue, and .12 for Angry.
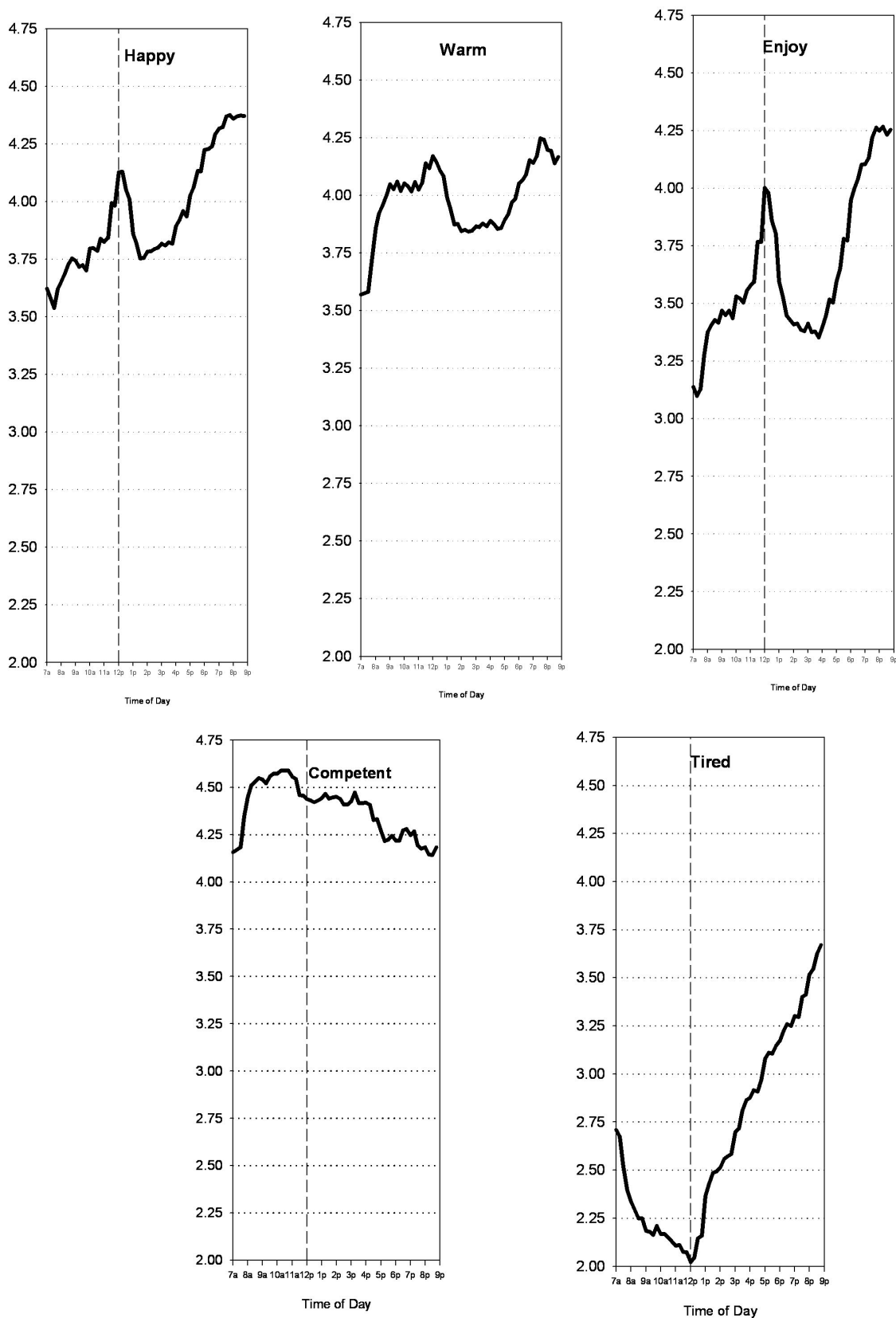
Figure 2. Diurnal cycles of the positive emotions (Happy, Warm, and Enjoy), Tired, and Competent. The difference between two points on a plot differ at the .05 alpha level when they differ by approximately .14 for Warm, .15 for Happy, .18 for Enjoy, .16 for Competent, and .16 for Tired.

Table 2

Results of Multilevel Analyses of Age, Time of Day (ToD), and Their Interaction on Emotion Adjectives (n = 909)

	F tests for age, hour-of-day, and interaction between age and time-of-day		
	Age	ToD	Age × ToD
a. Impatient	0.4	5.8***	1.8
b. Happy	6.1	13.9***	5.8***
c. Frustrated	3.4	5.8***	2.3
d. Depressed/Blue	0.8	2.4	1.8
e. Competent	21.1***	1.9	1.1
f. Hassled	1.9	3.8***	2.3
g. Warm	25.0***	7.2***	3.7***
h. Angry	2.3	3.8***	2.0
i. Worried	0.4	6.1***	2.9***
j. Enjoy	16.5***	12.8***	5.0***
k. Criticized	0.0	1.9	1.2
l. Tired	12.3***	15.8***	10.8***

Note. * $p < .01$. *** $p < .001$.

the young reported higher levels of tiredness than older participants. Thus, younger women clearly have less pleasant mornings than older women.

4. Optimal moment. Adan (Adan & Sanchez-Turet, 2001) suggested that women experience their optimal emotional point around 11 a.m. Our emotion data roughly replicate this pattern. During the day, the optimal point is around noontime as all negative emotions are reduced and all positive emotions are increased well above other points of the working day. However, evenings are even more positive and less negative than noon. Following the general approach behind the Affect Balance Checklist (Bradburn, 1969), which is based on a balance between positive and negative moods, we defined a single overall emotion score as the *z* score of happiness minus the *z* score of frustration. There was a distinctive association between this score and ToD, shown in Figure 4 (solid line), with a bimodal pattern.

Another consideration for the definition of the optimal moment of the day is tiredness. If tiredness is given a weighting equal to that of the mean of positive and negative emotions and then subtracted, the pattern changes as shown in Figure 4 (dotted line). High levels of tiredness, which are viewed here as reducing overall mood, increase the magnitude of the noon peak and greatly suppress the level of the evening hours.

5. Activities and diurnal cycles. Finally, we tested to which extent diurnal patterns remain when the influence of specific activities is removed. To do so, we selected three adjectives to represent the diurnal cycles observed in this study. They are Enjoy (representing positive adjectives), Frustrated (representing negative adjectives), and Tired (which has a diurnal rhythm that is different than Enjoy and Frustrated). Three multilevel models were computed, one for each adjective, with the activities recorded for each episode and ToD as predictor variables. Table 3 presents these the regression coefficients for each of the three models and significance levels

It is evident from examination of Table 3 that activities that are associated positively with Enjoy are negatively associated with Frustrated. The two exceptions are the activities, "On the phone" and "Taking care of children," which were not related to Enjoy, but were associated (in opposite ways) with Frustrated. It is also notable that several activities have no unique contribution to observed levels of enjoyment or frustration, including shopping and preparing food. Tiredness is associated with many fewer activities; those activities that were associated with tiredness were the same in sign as for the associations with frustration.

Our hypothesis was that the diurnal cycle of emotion would be reduced or flattened when the effect of activities were taken into account. Figure 5

presents diurnal plots for each adjective in two ways: without the effects of activities removed from the least square means for ToD and with the effects of activities removed from the means. Inspection of Figure 5 makes clear that a substantial flattening of the lines has occurred for Enjoy and Frustrated, but that there is almost no effect on the hourly means for Tired. Thus, for Positive Affect and Negative Affect, how time is spent also matters as well as it diurnal position.

Discussion

The two primary goals of this report were to demonstrate the feasibility of studying diurnal rhythms of emotions with the newly available DRM and to reexamine and extend several diurnal rhythm findings that emerged from earlier small-scale studies. With regard to the feasibility of using the DRM, our observation that individuals had little or no difficulty with the questionnaire suggests that the materials were understood and completed properly. The average duration of completion is in line with our expectations of the task, and obtaining comprehensive information about the activities and affect of a single day in well under an hour also shows the efficiency of the assessment procedure, at least compared with experience sampling methods where the training alone often requires an hour. It is also notable that the DRM can be administered in group settings, which is more efficient than individualized administration. The diurnal patterns of emotion adjectives appeared sensible and the association between daily activities and emotions provided further support for the validity of the assessment method. Overall, it is our opinion that the DRM has operational characteristics that make it suitable for studying diurnal cycles of daily experiences in large samples. Although we limited the experiences to activities and affect, it is notable that other content, such as symptom experiences or health behaviors, could easily be incorporated into the procedure by replacing or extending the current emotion adjectives. Similarly, other affect adjectives or characteristics of episodes could be used to meet particular research goals.

With regard to the diurnal cycles observed in this sample of Texas women, not only were several findings based on smaller-scale studies replicated, we detected diurnal rhythms that to our knowledge have not previously been reported. A consistent and strong bimodal pattern was found for positive and negative emotions. For the three positive adjectives, emotion levels during the work day had a peak at noon and a second peak starting at about 7 p.m. and the higher level lasted the rest of the evening. Conversely, peaks for the six negative adjectives were at about 10 a.m. and then at 4 or 5 p.m., although this pattern was relatively weak for some of the adjectives. One interpretation of this bipolarity is that the elevation of negative emotions was due to work and that lunchtime provided a respite from the demands of the work environment, reducing negative emotions (and increasing positive emotions); we discuss the association between activities and affect below.

Two emotion adjectives had cycles that did not conform to the bimodal pattern of the positive or negative adjectives: Competent and Tired. Competent was lowest in the morning, but quickly rose to the highest levels by midmorning, followed by a gradual decline throughout the day with an ultimate return to morning levels. We offer two speculative accounts. On the
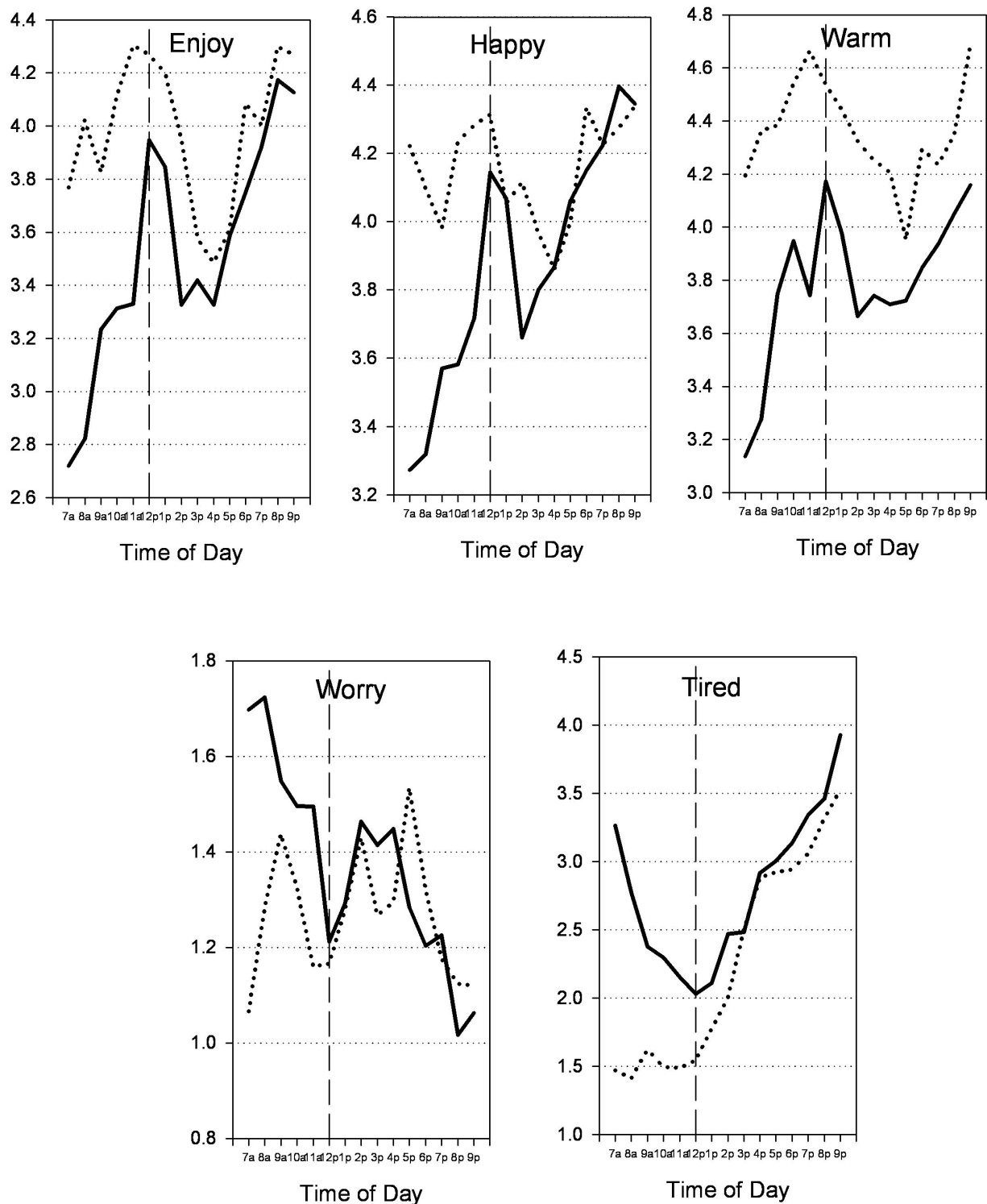
Figure 3.   Diurnal cycles of Enjoy, Happy, Warm, Worried, and Tired. Solid lines represent levels for those 30 and under and dashed lines for those 50 and older.

one hand, the observed decline in feeling competent may reflect the accumulation of problems and disappointments during the work day. On the other hand, feelings of competence may require that one meets a challenge. Challenges may be more likely to be encountered during the work day than during the periods that precede or follow the work day, and one's perceived likelihood of meeting work related challenges may decline as the work day nears its end.
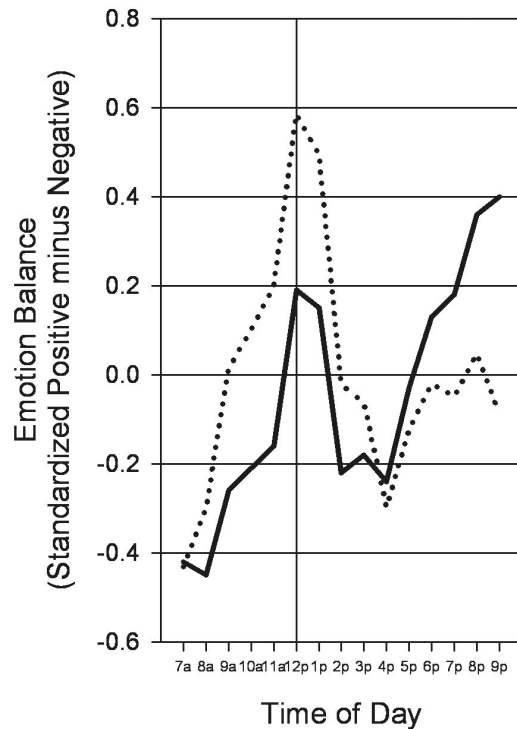
Figure 4. Diurnal cycle of optimal emotions. The solid line defines optimal as the standardized happiness score minus the standardized frustration score. The dotted line subtracts the standardized tiredness score from the first definition.

A V-shape was observed for Tired and this confirms prior real-time data analyses of this emotion (Stone, et al., 1996). Interestingly, on average, Tired reached its nadir at lunchtime and was followed by a steep rise through the remainder of the day. We and others previously speculated (Stone, et al., 1996; Wood, et al., 1992) that tiredness is largely independent of activities and may have a physiological basis: from midday onward, the longer we are awake, the more tired we become, leading, ultimately, to a strong desire for sleep. Following this argument, we suspect that whereas positive and negative emotion cycles may be very different on work versus nonwork days, the diurnal cycles of tiredness will be very similar for work and nonwork days.

With regard to the prior findings on rhythmicity, we replicated several findings from smaller scale studies. Diurnal cycles were observed for all of the emotion adjectives included in the DRM, although the strength of the associations varied widely. The form of the rhythms was similar, although not identical, to those observed in prior studies and that greatly increases our confidence that the DRM is a feasible and valid method for studying diurnal rhythms with large samples. Of particular interest were the analyses that examined diurnal rhythms taking into account the effects of the activities. For Enjoy and Frustrated, broadly representing positive and negative affects, diurnal patterns flattened considerably, indicating the important contribution of activities to diurnal cycles. A good example of this is the apparent pleasantness of lunch for this sample. All of the positive adjectives showed a sizable jump around noon and the negative adjectives showed a

corresponding decline. When the influence of activities (including lunch) was partialed from the means, the lunchtime peak in positive affect (and trough in negative affect) was also entirely eliminated. However, activities, though associated with the adjective, had almost no effect on the diurnal cycle of tiredness, a finding that replicates a previous result (Stone, et al., 1996).

Discrepancies between the present results and past results may be due to the current sample being limited to working women in a single geographic location, especially since males and females may have different diurnal cycles of affect. Our ability to detect patterns in all emotion adjectives may be a function of the increased statistical power afforded by the large number of participants examined, which we argue is facilitated by use of the DRM.

As an illustration of the potential application of the diurnal pattern of emotions to explain behavior, Figure 6 shows the diurnal pattern of tiredness (solid circles, right scale) and the diurnal pattern of time of death by suicides (gray bars, left scale) for a sample of women in Italy from 1994–1997. The latter series was reported by Preti and Mioto (Preti & Miotto, 2001) in 3-hour time intervals, the midpoint of which is displayed on the graph. The pattern of suicides is almost the mirror image of the pattern of tiredness. Suicides peak in the midmorning, near the time when the DRM sample was most alert. Suicides are least common late at night and very early in the morning, when the sample is most tired. We further find that the diurnal cycle of sleep for those who are depressed (as indicated by the response that keeping up enough enthusiasm to get things done in the past month has been a "big problem") bears an even stronger inverse relationship to the diurnal pattern of suicide (data not shown). One interpretation of this correspondence is that depression is more likely to lead to suicide when individuals have a sufficient level of energy to carry through with a plan to take their own lives. Another example of corresponding diurnal cycles is that of work accidents and tiredness (Fortson, 2004).

Table 3

Results of Multilevel Analysis of Time of Day and Activities on Enjoyment, Frustration, and Tired (n = 909)

		Frustration	
Activities	Enjoyment	Beta	Tired
a. Commuting	−.35***	.30***	−.04
b. Working	−.20***	.32***	−.08
c. Shopping	.15	.08	−.14
d. Preparing food	.00	.04	.04
e. Doing housework	−.60***	.22***	.17**
f. Taking care of children	−.02	.37***	.14*
g. Eating	.45***	−.39***	−.16***
h. Praying/worship	.38***	−.26**	.02
i. Socializing	.71***	−.41***	−.44***
j. Watching TV	.32***	−.20***	.05
k. Nap/resting	.30***	−.23**	.76***
l. Computer/internet	−.02	−.03	−.03
m. Relaxing	.57***	−.35***	.05
n. On phone	−.08	.25***	.05
o. Intimate relations	.82***	−.34*	−.55***
p. Exercising	.73***	−.55***	−.39**

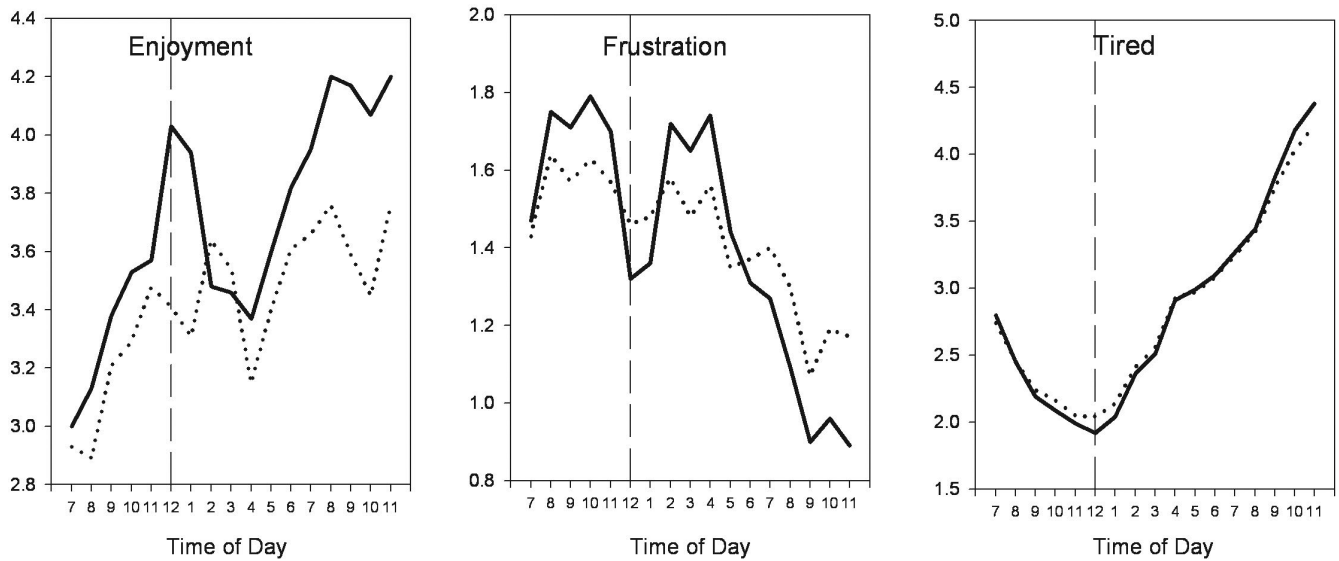*Note.*   * $p < .05$.   ** $p < .01$.   *** $p < .001$.

Figure 5. Diurnal cycles of Enjoyment, Frustration, and Tired without the effects of activities removed (solid lines) and with the effects of activities removed (dotted lines).

The results of these analyses are limited in several ways. Our sample was composed entirely of women and we limited the analyses to a working day. Certainly, studies of diurnal cycles of emotion should be extended to men, who may have different patterns of emotions throughout the day. We also expect that large differences in cycles will be observed on nonwork days compared with working days; daily activities are likely to be more loosely linked to time of day on nonwork days and may display less distinctive diurnal rhythms. Regarding the DRM, it is a newly developed technique, which should be kept in mind when considering these results.

In summary, researchers may wish to consider using the DRM for examining diurnal rhythms of emotion. It is feasible to administer to large samples of people, it can be readily modified to study other emotions, behaviors, or symptoms of interest, and it incorporates methodological features to reduce memory bias. A limitation of the method is that it only captures the experiences of a single day and some research questions—for example, whether
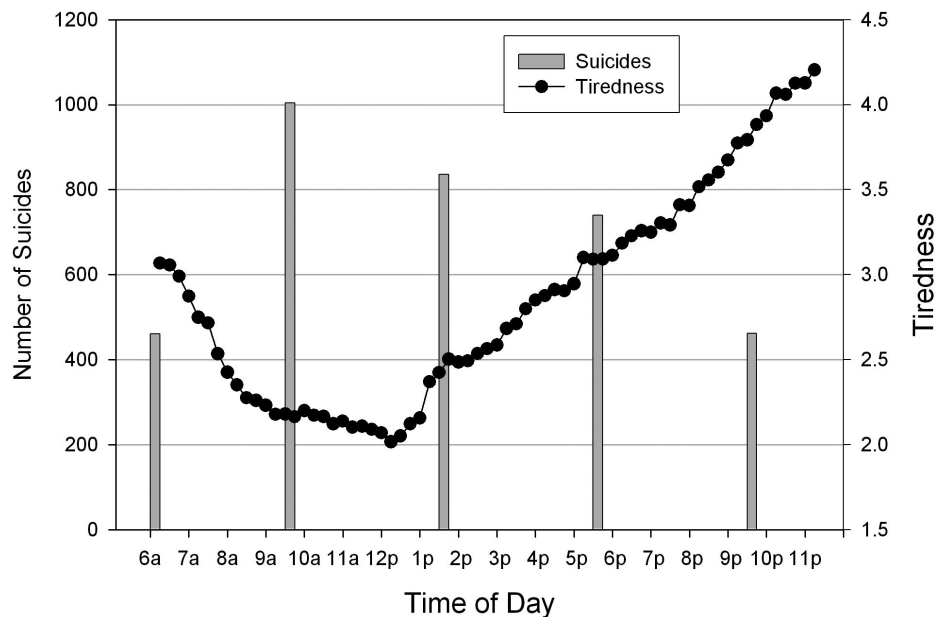

Figure 6. Diurnal cycle of suicides of Italian women (1994–1997) and the cycle of tiredness.

work days differ from nonwork days or whether stable individual differences in diurnal patterns exist—require the assessment of multiple days.

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