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# Morningness–eveningness and intelligence: early to bed, early to rise will likely make you anything but wise![1]

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**Abstract**

Research examining various psychological correlates of circadian type (also known as diurnal preference) has been, over the years, quite expansive. A notable omission within this research program would appear a systematic exploration of the relation between intelligence and morningness–eveningness. The present study redressed this imbalance. 420 participants performed two self-report inventories assessing circadian type, as well as measures of intelligence from two psychometric batteries: CAM-IV and the ASVAB. The results indicate that, contrary to conventional folk wisdom, evening-types are more likely to have higher intelligence scores. This result is discussed in relation to current theories concerning the nature of human cognitive abilities. 

*Keywords:* Circadian rhythms; Diurnal preference; Morningness–eveningness; Intelligence; Working memory; Processing speed

## 1. Introduction

The term 'circadian' denotes: "The near 24 h physiologic rhythm that has been observed under free-running conditions, at every system level in nearly all plants and mammals, under

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[1] Please note that the views expressed herein are those of the authors and are not part of official USAF policy.

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near constant environmental conditions'' (Brown, 1982, p. 9)[2]. Within individual differences approaches to this phenomenon, there is a stated assumption that there exists definite *types* corresponding to diurnal preference (e.g. Kerkhof, 1985; Tankova, Adan, & Buela-Casal, 1994; Roberts, Irvine, & Kyllonen, 1998). This notion has a long history with anecdotal evidence deriving from a number of sources, including Johnson's purported ''love of lying till noon'' (Boswell, 1785/1961), to populist notions of the 'early bird' (or 'lark') and 'night owl'. Following the pioneering research of Kleitman (1939/1963) these propensities were formally conceptualized as a trait, lying along a continuum, that has come to be known as the morningness–eveningness (M–E) dimension.

In a major review of the literature examining individual differences in circadian types, Tankova et al. (1994) report correlations between M–E and a host of variables, including: gender, age, personality and drug (especially caffeine) consumption. A surprising omission from the list of psychological correlates of diurnal type reviewed by Tankova et al. was cognitive ability variables. It is worth noting that there is a rather expansive literature documenting so-called 'time-of-day' effects on a number of cognitive processes (e.g. memory) that are clearly central to intelligent behavior (for example, see Blake, 1967; Colquhoun, 1971; Kelly, 1995). The initial question that we asked was whether the lack of research examining correlations between diurnal preference and intelligence was an oversight of the otherwise comprehensive Tankova et al. (1994) review or a real phenomenon.

A search of the PsycLIT (1998) database with 'morningness', 'eveningness', 'diurnal type' and 'circadian' combined in all pair-wise combinations with 'intelligence', 'cognitive ability' and 'factors', failed to provide any hits that were appropriate to our concerns. We substituted, where appropriate, terms signifying prominent measures of ability (e.g. 'WAIS-R'), specific intelligence constructs (e.g. 'fluid intelligence [Gf]') and measures of the M–E dimension (e.g. 'diurnal type scale') in various combinations, with a similar (negative) outcome. It would appear that there has been no systematic attempt to examine relations between intelligence and diurnal preference, although a folk psychology clearly exists suggesting otherwise (e.g. ''early to bed, early to rise makes you healthy, wealthy and *wise*''). The aim of the present study was to redress this imbalance., More formally, we sought to examine correlations between circadian type and cognitive ability constructs since there would appear no information available on this relation in the current literature.

## 2. Method

### *2.1. Participants*

Participants were 420 (73 female) United States Air Force (USAF) recruits undergoing their sixth week of basic training. The age of the sample ranged from 17 to 34 with a mean of 20.20 years (S.D. = 2.30).

[2] The term circadian comes from the Latin, *circa* + *dies*, about a day (see Halberg, Halberg, Barnum, & Bittner, 1959). In principle, however, these rhythms actually range from 22 to 28 h.

It should be noted from the outset that this sample is especially interesting from the point of view of their so-called chronobiology. Because all of the enlistees were some six weeks into their training period, they had been exposed to homogenous sleep–wake cycles, dietary intake and social constraints. Elsewhere each of these factors has been shown to influence circadian rhythms (e.g. see Costa, Lievore, Ferrari, & Gaffuri, 1987; Minors, Rabbitt, Worthington, & Waterhouse, 1989). Moreover, because of the lengthy period of their training protocol, each participant had time to phase shift their circadian rhythms to this newly imposed regime, ruling out adjustment to phase-shift as a confounding variable in the experimental context.

### 2.2. Design

Participants completed two self-report measures of circadian type: the Morningness–Eveningness Questionnaire (Horne & Östberg, 1976) and the Composite Circadian Scale (Smith, Reilly, & Midkiff, 1989). For present purposes, these two tests were computerized and were presented randomly at the beginning and end of the test session[3]. Information on intelligence was obtained during the same session by having participants perform a selection of tests from the Cognitive Abilities Measurement-Version IV (Kyllonen, 1994). Because each member of the sample was selected according to his or her Armed Services Vocational Aptitude Battery (ASVAB; US Department of Defense, 1984) score, informed consent to use this information was also obtained[4]. A brief description of all tests used in the present investigation follows.

### 2.3. Circadian measures

#### 2.3.1. Morningness–Eveningness Questionnaire (MEQ)

The MEQ is composed of 19 self-report items. Each item required participants to denote the degree to which they prefer definite morning (or evening) activities. For example: "Assuming adequate environmental conditions, how easy do you find getting up in the mornings?" (1, not at all easy; 2, not very easy; 3, fairly easy; 4, very easy).

#### 2.3.2. Composite Circadian Scale (CCS)

This 13 item-scale actually contains a mixture of items from the MEQ and the Diurnal Type Scale developed by Torsvall and Åkerstedt (1980). To reduce methodological artifacts, Smith et

[3] Note that due to administrative constraints placed on Air Force enlistees the circadian type questionnaires and CAM-IV tests were administered to all participants during the morning (i.e. 8.00 a.m.–12.00 noon). This places evening types at something of a disadvantage because all evidence points to the fact that these time zones are outside those in which they reach their performance peak (Kelly, 1995). ASVAB test scores, on the other hand, were randomly obtained over the course of the day (a function of this tests widespread use in the selection context across the USA (see, for example, Foley & Rucker, 1989)).

[4] Because the Air Force is currently updating its methods of archiving ASVAB data, some 26% of participant's records on this variable were missing by the time the investigation was complete. While there are a number of statistical techniques for treating missing data, the sample size was considered sufficiently large to report the 'uncorrected' correlations for each variable. The actual number of participants for which complete data were obtained in each part of the study is given at the bottom of Table 2.

al. (1989) modified Likert-type responses from the former scale so that all items adhered to a four- (or five-) choice format. For example: ‘‘Considering only your own ‘feeling best’ rhythm, at what time would you get up if you were entirely free to plan your day?’’ (5 = 5.00 to 6.30 a.m.; 4 = 6.30 to 7.45 a.m.; 3 = 7.45 to 9.45 a.m.; 2 = 9.45 to 11.00 a.m.; 1 = 11.00 a.m. to 12 noon).

### 2.4. Armed Services Vocational Aptitude Battery (ASVAB)

The ASVAB is a multiple aptitude measure composed of the following ten sub-tests: general science, arithmetic reasoning, word knowledge, paragraph comprehension, numerical operations, coding speed, auto and shop information, mathematics knowledge, mechanical comprehension and electrical information[5]. Although this test is not so well known outside the USA, it is a particularly prominent psychometric instrument, widely implemented in a variety of educational, selection and research settings (Murphy & Davidshofer, 1998)[6]. Indeed, within contemporary psychology, it has been proclaimed that ‘‘the ASVAB is representative of the state of the art in multiple aptitude batteries’’ (Ree & Carretta, 1995, p. 269). These features suggest it to be a particularly efficacious measure of cognitive abilities to include in the present design.

### 2.5. Cognitive Abilities Measurement (Version IV) Battery (CAM-IV)

Kyllonen (1994) provides a detailed exposition of the CAM-IV battery and, in particular, the conceptual framework upon which it is based (see also Kyllonen, 1986; Kyllonen & Christal, 1989). Perhaps the most important of the constructs assessed by CAM-IV are working memory, processing speed and temporal processing. Although there are a number of measures of each construct available to the researcher (e.g. at least nine indices of working memory and processing speed) constraints on testing time dictated a judicious selection of tasks from within the battery. Thus, working memory was assessed using the XYZ-assignment and four-term ordering tasks of CAM-IV, while processing speed was measured using the X-assignment and two-term ordering. A single measure of temporal processing (estimating clock time) was employed.

[5] Many sites on the Web give both descriptions of all sub-tests and sample items from the ASVAB. One such site is <http://www.goarmy.com/asvab/testa.htm>

[6] The ASVAB has been so influential in educational guidance that a whole program is named after it (i.e. the ASVAB Career Exploration Program; Defense Manpower Data Center, 1996). In the selection context, it is estimated that performance on the ASVAB is a major determinant in the career choices of over 1.3 million young Americans per annum (Kaplan & Saccuzzo, 1997, p. 365). In empirical instantiations, hundreds of studies, including those forming the core data set of the Bell Curve (Herrnstein & Murray, 1994) are devoted to (or employ) the ASVAB somewhere within their experimental design (Roberts & Goff, 1998).

## 3. Results

### 3.1. Preliminary analysis: circadian measures

Reliabilities for both the MEQ and CCS were calculated using Cronbach's coefficient alpha. The values obtained (0.72 and 0.81, respectively) were within the expected range, being close to those reported in earlier studies employing these instruments (see e.g. Neubauer, 1992; Greenwood, 1994). However, a somewhat unexpected outcome was the rather high mean scores obtained by the present group on each circadian scale: mean (MEQ) = 54.36, mean (CCS) = 36.97 (S.D. = 7.79 and 6.20, respectively). In fact, the present values are among the highest reported in the extant literature (cf. Horne & Östberg, 1976; Smith et al., 1989; Neubauer, 1992). The magnitude of these scores indicates that the sample is predisposed towards morningness. This finding is interpretable in light of the composition of the present sample, which is plausibly self-selected on this dimension. In contrast, almost all previous research had examined either university groups or individuals undergoing rotating shifts, samples known to have a predilection towards evening behaviors (e.g. Mecacci & Zani, 1983). In turn, this finding supports the suggestion of Kerkhof (1985, p. 86) that "it is advisable to adapt and validate the (circadian) questionnaire for the particular country or culture where its use is considered".

Elsewhere we report an exploratory factor analysis of each scale that resulted in a series of rather interesting outcomes (see Roberts et al., 1998). With respect to the MEQ, it became apparent that minimally three factors were actually being assessed: evening (affect), morning (affect) and morning (effort). The correlation between the two morning factors was moderate (0.44) while the correlation between both morning factors and evening (affect) was near zero. Upon detailed examination of the literature, we discovered that this finding draws ready parallels with two recent studies examining the MEQ (see Smith, Tisak, Bauman, & Green, 1991; Brown, 1993). Because we felt that the issue of the multidimensionality of diurnal preference needed to be explored further, factor scores corresponding to three dimensions, evening (affect), morning (affect) and morning (effort), were extracted from the MEQ[7].

Exploratory factor analysis of the CCS, on the other hand, indicated two factors, a general morningness construct and a factor dominated by a single item relating to evening activities. This item asks: at what time of the evening do you feel tired and as a result in need of sleep?

[7] The theoretical implications of this multidimensional structure are discussed fully in Roberts et al. (1998). Briefly, we argue there that morningness and eveningness are better understood as two separate continua. In the model proposed therein, high morning and low evening scores subsume classical notions of 'morningness'. 'Eveningness', on the other hand, corresponds to high evening and low morning scores. Two other types are defined within this model. High morning and high evening scorers correspond to what Roberts et al. (1998) label 'energetic' types, though these individuals may also be characterized as phase tolerant. Low evening and low morning scorers correspond to 'Languid' types (see, for example, Folkard, Monk, & Lobban, 1979). (Although as in the preceding account they might also be characterized by their ability to adjust to circadian phase and therefore be labeled phase intolerant). The reader may note parallels with Eysenckian theory (see, for example, Eysenck & Eysenck, 1964), particularly in terms of the hypothesized interaction between the dimensions of extraversion and neuroticism. We refrain from applying this 'new' model to the present data set because of our belief that eveningness is not well defined by the MEQ (Roberts & Irvine, 1998).

In light of this analysis and in the conviction that this scale could capture a general factor of morningness, we removed this evening item from the scale. Resulting analyses are based, therefore, on what we conceptualize as three lower-order factors of diurnal preference and a general morningness construct (see Roberts et al., 1998).

### 3.2. Preliminary analyses: cognitive ability measures

Mean performance of participants on each of the CAM-IV and ASVAB sub-tests were calculated, along with intercorrelations. In each case, this series of results (available from the authors upon request) were similar to normative samples. Of course, it is possible to provide a breakdown of the relation that each of the five tests of CAM-IV and ten sub-tests of the ASVAB share with circadian constructs. However, it seemed more expedient to report correlations with composites, which are often cited in the literature. In the case of the ASVAB, there are five such scales: administration, electronics, general, mechanical and air force qualifying (AFQT). These scales reflect various measures of practical utility in the selection context. The last of these scales, the AFQT, is thought to provide a fallible index of the general intelligence construct (i.e. psychometric *g* (e.g. see Stauffer, Ree, & Carretta, 1996)). However, it has been argued that the AFQT is more likely as an index of acculturated abilities (Roberts & Goff, 1998; Roberts, Pallier, & Goff, 1999). In the case of CAM-IV tests, measures tapping more than one knowledge domain (e.g. verbal as opposed to spatial processes) are thought to produce particularly valid measures of the underlying construct. Therefore, measures were averaged across the two working memory and processing speed tasks. Note that working memory is closer to the general (and, therefore, fluid) intelligence constructs than any other cognitive ability measure forming the present battery (see Kyllonen & Christal, 1990).

Table 1

Means and standard deviations for the cognitive ability measures used in the investigation. (1) ASVAB composites were formed by combining sub-tests in the following manner: (i) administration: word knowledge, paragraph comprehension, mathematics knowledge and coding speed; (ii) mechanical: arithmetic reasoning, mechanical comprehension, auto and shop information and electronics information; (iii) electronics: arithmetic reasoning, mathematics knowledge, electronics information and science; (iv) general: word knowledge, paragraph comprehension, arithmetic reasoning and mechanical comprehension; (v) AFQT: word knowledge, paragraph comprehension, arithmetic reasoning and mathematics knowledge (see Herrnstein and Murray, 1994, pp. 579–592 for a detailed exposition of technical issues related to this measure). (2) The dependent variable in the processing speed and temporal processing tasks was time (measured in ms). In the working memory tasks, the score reflects percentage correct

| Cognitive ability score | Mean | S.D. |
|---|---|---|
| ASVAB administration | 69.19 | 19.94 |
| ASVAB electronics | 63.56 | 17.37 |
| ASVAB general | 62.74 | 17.72 |
| ASVAB mechanical | 56.67 | 22.04 |
| Air force qualifying | 219.21 | 16.67 |
| Processing speed | 2049.11 | 411.62 |
| Temporal processing | 7288.45 | 734.70 |
| Working memory | 78.84 | 12.92 |

Means and standard deviations for the five ASVAB and three CAM-IV composites are reproduced in Table 1. Note that the mean of the ASVAB normative sample on any one of the occupational composites is 50 (S.D. = 10) (see Foley & Rucker, 1989). In other words, the present sample has performed above average on the ASVAB tests. There are two explanations for this occurrence. The first is that the ASVAB, like many other cognitive ability measures, is likely subject to item drift, encapsulated within the so-called Flynn effect (Flynn, 1984, 1987). The other is that the USAF has in times of (relative) global peace and technological advances reduced the number of its personnel (Hammer, 1997), thereby resulting in more stringent selection criteria. Consistent with both propositions is the fact that means and standard deviations for ASVAB normative composites were obtained from the 1980 American Youth Population (Foley & Rucker, 1989). Nevertheless, the values obtained on the CAM-IV measures are close to those reported in various validation studies conducted by the USAF Research Laboratory on this battery using similar participants (see, for example, Goff, Sawin, & Earles, 1997).

### *3.3. Correlations between circadian type and intelligence measures*

The correlations that the ASVAB composites, working memory, processing speed and temporal processing indices share with the three lower-order circadian factors and general morningness (CCS-R) construct are presented in Table 2. Inspection of Table 2 reveals a particularly striking outcome, the cognitive ability measures consistently share low to moderate (and interpretable) correlation with the circadian indices[8]. Given that the morning scales have been scored in such a way that higher scores indicate a greater predisposition towards morning behaviors and that the evening scale has been reflected, it would appear that evening-types are likely to be more intelligent. This outcome happens to hold true for disparate cognitive capabilities (e.g. acculturated intelligence versus working memory) and various factors of circadian type (aligned, as they are, on two strata).

## 4. Discussion

The correlations reported in Table 2, while not large, are worth noting for the consistency with which they are manifest across disparate measures of cognitive processing and different factors of M–E. In general, these results indicate individuals high in eveningness are more likely to do well on measures of memory, processing speed and so forth, even when these cognitive tasks are performed during the morning. Further, the construct that would appear closest conceptually to general intelligence (i.e. working memory) shares the highest correlation with circadian measures, including a significant correlation with the general morningness factor. Finally, the highest correlations found with respective circadian measures occurs in a

[8] Scores on the two time-related constructs (i.e. processing speed and temporal processing) have been reflected in order to facilitate interpretation. Therefore, the moderate correlations observed with respect to these measures is consistent with the general premise of better performance manifesting itself in evening-types.

Table 2
Correlations of various intelligence and cognitive processing composites with the various circadian measures examined in the investigation. (1) Scores on the evening (affect) dimension have been reflected in order to facilitate interpretation (i.e. high scores indicate a predisposition towards eveningness). (2) $N = 310$ for ASVAB data, $N = 419$ for all CAM-IV tests. $^{**}p < 0.01$, $^{*}p < 0.05$

| | Correlation with: | | | |
|---|---|---|---|---|
| | evening (affect) | morning (affect) | morning (effort) | CCS-R total |
| *Cognitive ability score* | | | | |
| ASVAB administration | 0.03 | −0.10* | −0.09 | −0.07 |
| ASVAB electronics | 0.11* | −0.11* | −0.13** | −0.04 |
| ASVAB general | 0.12* | −0.14** | −0.15** | −0.06 |
| ASVAB mechanical | 0.12* | −0.03 | −0.07 | 0.04 |
| Air force qualifying | 0.11* | −0.12* | −0.14** | −0.05 |
| Processing speed | 0.10* | −0.11* | −0.14** | −0.10* |
| Temporal processing | 0.16** | −0.03 | −0.09 | −0.02 |
| Working memory | 0.14** | −0.14** | −0.19** | −0.14** |

construct that we have designated morning (effort), arguably supporting the importance of considering these lower-order factors of diurnal preference.

Three pieces of evidence from the wider psychological literature are worth noting, as they would appear to converge with the present findings. Firstly, as mentioned earlier in the paper, researchers have consistently reported that university students are biased towards the evening dimension. The present finding would appear interpretable in light of the fact that entry to higher education is contingent on superior cognitive capabilities. Secondly, it has been noted that the relation between age and circadian type is particularly robust, age is positively associated with morningness (e.g. see Kerkhof, 1985; Tankova et al., 1994). It has been suggested that this relation is the result of the circadian system pushing the individual towards a morning-type orientation with advancing age (e.g. see Monk et al., 1991). It would appear consequential that there is also an expansive literature documenting the decline of cognitive abilities with advancing age (e.g. Horn & Hofer, 1992). Finally, almost all models of cognitive ability suggest that the individual's ability to adapt to their environment is the defining feature of high intelligence (e.g. Sternberg, 1985). Within the literature on circadian rhythms, a now classic article by Richter (1977) argues that control of fire for lighting changed human activity forever and increased survivability beyond that of other animals. Under this premise, it would not seem too fanciful to argue that those able to adapt to evening schedules were among the fittest of the emerging *Homo sapiens*.

Each of the above explanations would seem to suggest that the correlations reported herein are very much attenuated by restrictions in range on variables such as age and intelligence. Indeed, the circadian type construct might also be restricted in range for the present sample. As a reviewer of this paper pointed out, almost all earlier studies examining M–E were conducted with university students, who might be less restricted in range on the M–E dimension. Nevertheless, it is worth noting that students (perhaps more than any other social group) are atypical, they can actually choose their work time to match their diurnal preference (albeit for a rather short period of their life). Moreover, whether or not students represent better samples to test theories of circadian type seems a moot point because in most accounts M–E has been viewed as a trait.

The present results are obviously in need of replication, not least because, in the course of the present study we became concerned with various properties of the instruments that we employed to assess diurnal preference. Elsewhere we note that while the psychometric properties of the MEQ and CCS are adequate as a whole (especially when compared to others found in the literature), there are several problematic items (see Roberts et al., 1998). Furthermore, as alluded to earlier, the precise conditions under which cut-off scores should be employed across samples is uncertain, rendering the most often used aspect of these scales, identification of extreme types, highly problematic. These shortcomings are compounded from the point of view of test construction, current instruments do not employ a fixed scale and are clumsily worded. We are presently engaged in designing and validating a new instrument that would allay these criticisms and in the process, provide a more rigorous test of the current hypothesis (Roberts & Irvine, 1998).

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## References

Blake, M. J. F. (1967). Time of day effects on performance in a range of tasks. *Psychonomic Science*, *9*, 349–350.

Boswell, J. (1785/1961). *Journal of the tour of the Hebrides with Samuel Johnson*. New York: McGraw-Hill.

Brown, F. M. (1982). Rhythmicity as an emerging variable for psychology. In F. M. Brown, & R. C. Graeber, *Rhythmic aspects of behavior* (pp. 3–38). Hillsdale, NJ: Erlbaum.

Brown, F. M. (1993). Psychometric equivalence of an improved Basic Language Morningness (BALM) Scale using industrial population with comparisons. *Ergonomics*, *36*, 191–197.

Colquhoun, W. P. (1971). Circadian variations in mental efficiency. In W. P. Colquhoun, *Biological rhythms and human performance* (pp. 39–107). London: Academic Press.

Costa, G., Lievore, F., Ferrari, P., & Gaffuri, E. (1987). Usual meal times in relation to age, sex, work activity and morningness–eveningness. *Chronobiologica*, *14*, 383–391.

Defense Manpower Data Center (1996). *Counselor manual for the Armed Services Vocational Aptitude Battery Career Exploration Program*. Seaside, CA: Author.

Eysenck, H. J., & Eysenck, S. B. G. (1964). *Manual of the Eysenck Personality Inventory*. London: University of London Press.

Flynn, J. R. (1984). The mean IQ of Americans: massive gains 1932 to 1978. *Psychological Bulletin*, *95*, 29–51.

Flynn, J. R. (1987). Massive gains in 14 nations: what IQ tests really measure. *Psychological Bulletin*, *101*, 171–191.

Foley, P., & Rucker, L. S. (1989). An overview of the Armed Services Vocational Aptitude Battery (ASVAB). In R. F. Dillon, & J. W. Pellegrino, *Testing: theoretical and applied perspectives* (pp. 16–35). New York: Praeger.

Folkard, S., Monk, T. H., & Lobban, M. C. (1979). Towards a predictive test of adjustment to shift work. *Ergonomics*, *22*, 79–91.

Goff, G. N., Sawin, L., & Earles, J. (1997). *The factor structure of two abilities tests: APT versus ASVAB*. Paper presented at the 105th Annual American Psychology Association Conference, Chicago, IL, August, 1997.

Greenwood, K. M. (1994). Long-term stability and psychometric properties of the Composite Scale of Morningness. *Ergonomics*, *37*, 377–383.

Halberg, F., Halberg, E., Barnum, C. P., & Bittner, J. J. (1959). Physiologic 24-hour periodicity in human beings and mice, the lighting regimen and daily routine. In R. B. Withrow, *Photoperiodism and related phenomena in plants and animals* (pp. 803–878). Washington, DC: American Association for the Advancement of Science.

Hammer, D. (1997). *Air Force operational viewpoint*. Presentation at The United States Air Force Office of Scientific Research (AFSOR) Chronobiology and Neural Adaptation Conference, Colorado Springs, CO, September, 1997.

Herrnstein, R. J., & Murray, C. (1994). *The Bell curve: intelligence and class structure in American life*. New York: Free Press.

Horn, J. L., & Hofer, S. M. (1992). Major abilities and development in the adult period. In R. J. Sternberg, & C. Berg, *Intellectual development* (pp. 44–99). New York: Cambridge University Press.

Horne, J., & Östberg, O. (1976). A self-assessment questionnaire to determine morningness–eveningness in human circadian rhythms. *International Journal of Chronobiology*, *4*, 97–110.

Kaplan, R. M., & Saccuzzo, D. P. (1997). *Psychological testing: principles, applications, and issues* (4th ed). Pacific Grove, CA: Brooks-Cole.

Kelly, T. L. (1995). *Circadian rhythms: importance for models of cognitive performance*. Naval Research Center Technical Report No. 96-1. Bethesda, MD.

Kerkhof, G. A. (1985). Inter-individual differences in the human circadian system. A review. *Biological Psychology*, *20*, 83–112.

Kleitman, N. (1939/1963). *Sleep and wakefulness*. Chicago, IL: University of Chicago Press.

Kyllonen, P. C. (1986). Theory-based cognitive assessment. In J. Zeidner, *Human productivity enhancement: organizations, personnel, and decision making*, *Vol. 1* (pp. 338–381). New York: Praeger.

Kyllonen, P. C. (1994). CAM: a theoretical framework for cognitive abilities measurement. In D. K. Detterman, *Current topics in human intelligence*, *Vol. 4: Theories of intelligence* (pp. 307–359). Norwood, NJ: Ablex Publishing Corporation.

Kyllonen, P. C., & Christal, R. E. (1989). Cognitive modeling of learning abilities: a status report of LAMP. In R. F. Dillon, & J. W. Pellegrino, *Testing: theoretical and applied perspectives* (pp. 146–173). New York: Praeger.

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working memory capacity?! *Intelligence*, *14*, 389–433.

Mecacci, L., & Zani, A. (1983). Morningness–eveningness preferences and sleep-waking diary data of morning and evening types in student and worker samples. *Ergonomics*, *26*, 1147–1153.

Minors, D. S., Rabbitt, P. M. A., Worthington, H., & Waterhouse, J. M. (1989). Variations in meals and sleep-activity patterns in aged subjects: its relevance to circadian rhythm studies. *Chronobiology International*, *6*, 139–146.

Monk, T. H., Reynolds III, C. F., Buysse, D. J., Hoch, C. C., Jarrett, D. B., Jennings, J. R., & Kupfer, D. J. (1991). Circadian characteristics of healthy 80-yr-olds and their relationship to objectively recorded sleep. *Journal of Gerontology*, *46*, M171–M175.

Murphy, K. R., & Davidshofer, C. O. (1998). *Psychological testing: principles and applications* (4th ed). Upper Saddle River, NJ: Prentice Hall.

Neubauer, A. C. (1992). Psychometric comparison of two circadian rhythm questionnaires and their relationship with personality. *Personality and Individual Differences*, *13*, 125–131.

PsycLIT [Database]. (1974–1997, April 1998). Washington, DC: American Psychological Association (Producer). SilverPlatter (Distributor).

Ree, M. J., & Carretta, T. R. (1995). Group differences in aptitude factor structure on the ASVAB. *Educational and Psychological Measurement*, *55*, 268–277.

Richter, C. P. (1977). Discovery of fire by man: its effects on his 24-hour clock and intellectual and cultural evolution. *The John Hopkins Medical Journal*, *141*, 47–61.

Roberts, R. D., & Goff, G. N. (1998). The Armed Services Vocational Aptitude Battery (ASVAB): little more than acculturated learning (Gc). In *Proceedings of the 39th Annual Conference of the International Military Testing Association. San Antonio, TX* (pp. 379–394). AFPC/ALHRM/AFOMS.

Roberts, R. D. & Irvine, S. (1998). Development and construct validation of the Lark-Owl (chronotype) indicator (LOCI): interim report (August, 1998). Unpublished manuscript.

Roberts, R. D., Irvine, S., & Kyllonen, P. C. (1998). Personality and circadian type: a review and empirical investigation. Unpublished manuscript.

Roberts, R. D., Pallier, G., & Goff, G. N. (1999). Sensory processes within the structure of human cognitive abilities. In P. L. Ackerman, P. C. Kyllonen, & R. D. Roberts (Eds.), *Learning and individual differences research: process, trait, and content determinants* (pp. 355–368). Washington DC: American Psychological Association.

Smith, C. S., Reilly, C., & Midkiff, K. (1989). Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. *Journal of Applied Psychology*, *74*, 728–733.

Smith, C. S., Tisak, J., Bauman, T., & Green, E. (1991). Psychometric equivalence of a translated circadian questionnaire: implications for between- and within-population assessments. *Journal of Applied Psychology*, *76*, 628–636.

Stauffer, J. M., Ree, M. J., & Carretta, T. R. (1996). Cognitive-components tests are not much more than g: an extension of Kyllonen's analyses. *The Journal of General Psychology*, *123*, 193–205.

Sternberg, R. J. (1985). *Beyond IQ: a triarchic theory of human intelligence*. Cambridge University Press: Cambridge.

Tankova, I., Adan, A. A., & Buela-Casal, G. (1994). Circadian typology and individual differences: a review. *Personality and Individual Differences*, *16*, 671–684.

Torsvall, L., & Åkerstedt, T. (1980). A diurnal type scale. Construction, consistency and validation in shift work. *Scandinavian Journal of Work, Environment and Health*, *6*, 283–290.

US Department of Defense (1984). *Test manual for the Armed Services Vocational Aptitude Battery (DoD 1340.12AA)*. North Chicago, IL: US Military Entrance Processing Command.