The relationship between morningness–eveningness, time-of-day, speed of information processing, and intelligence

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Received 22 June 1998; received in revised form 24 November 1999; accepted 12 January 2000

Abstract

Morningness–Eveningness refers to individual differences in circadian phase position of spontaneous sleep–wake rhythms and to subject alertness. There is some evidence indicating that performance on cognitive tasks may be influenced by Morningness–Eveningness and time-of-day. Given the potential importance of such a finding for the assessment of cognitive ability we conducted a study assessing the relationship between Morningness–Eveningness, time-of-day, and performance on the Multidimensional Aptitude Battery IQ (MAB-IQ) and Inspection Time (IT) task. Twenty male and 50 female participants classified according to their scores on the Morningness–Eveningness dimension (Horne & Östberg, 1976) were administered the MAB and IT tasks in the morning (0900 h) and in the late afternoon (1500 h). No significant effect of time of testing, and Morningness–Eveningness was observed except for the Spatial subtest of the MAB. Morning Type-participants performed significantly worse in the morning session in Spatial subtest and better in the late afternoon session and Evening Type-participants performed significantly better in the morning than in the late afternoon session. These results do not support the hypothesis that there is a reliable relationship between Morningness–Eveningness, time-of-day and cognitive ability. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Circadian rhythms; Morningness–Eveningness; Intelligence; Time-of-day; Processing speed

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1. Introduction

1.1. Morningness–Eveningness

Morningness–Eveningness (M–E) refers to individual differences in circadian phase position of spontaneous sleep–wake rhythms and to subjective alertness. Individuals can be classified as either Morning Types (MTs), Evening Types (ETs) or the intermediate type-Neither Types (NTs) with the latter being the most common classification (Lacoste & Wetterberg, 1993). Hur, Bouchard and Lykken (1998) have reported that 50% of the variability in M–E is attributable to genetic variance.

MTs rise earlier in the day, retire earlier at night and show less variable sleep duration compared to ETs. Consistent with these distinctions is the observation that oral temperatures of MTs generally peak 2 h earlier than that of ETs (Lacoste & Wetterberg, 1993). In addition, MTs also begin the day with higher body temperature and record a steeper rise in temperature in the morning relative to that of ETs. Conversely, the temperature of ETs rises steadily during the day and peaks in the middle evening. After reaching their respective peaks, the rates of decline of body temperature for MTs and ETs are the same (Horne, Brass & Pettitt, 1980).

The categorization of M–E types is typically achieved from self-report questionnaires. The most commonly used questionnaire for assessing M–E is the Horne and Østberg (1976) Morningness–Eveningness Questionnaire (MEQ) which has been translated into Italian, Spanish and Japanese, and successfully validated against a range of physiological responses (Ishihara, Saitoh, Inoue & Miyata, 1984).

Physiological measures such as adrenaline excretion (Patkai, 1971), skin conductance (Wilson, 1990) and salivary cortisol levels (Bailey & Heitkemper, 1991) have been shown to differentiate MTs and ETs. MTs excrete more adrenaline and display larger auditory and visual evoked potentials in the morning than in the evening whilst ETs show an opposite tendency (Kerkhof, Korving, Willemsen, Geest & Rietvald, 1980).

M–E types also differ on psychological processes (Costa, Lievore, Casaletti & Gaffuri, 1989), and circadian rhythmicity has been found to be more successful in discriminating individuals than personality traits (Tankova, Adan, & Buela-Casal, 1994). Nonetheless, Eveningness has been reported to correlate with extraversion, specifically sociability in some (Wilson, 1990; Neubauer, 1992) but not in all studies (Matthews, 1987).

In a study using a simulated production-line inspection task, MTs performed better than ETs in the morning while ETs performed better than MTs in the evening (Horne et al., 1980). When performances in the morning, early afternoon, and evening were compared, Horne et al. reported that the greatest differences in performance between M–E types occurred in the morning while least differences were found during early afternoon.

Roberts and Kyllonen (1999) have recently examined cognitive performance of MTs and ETs in United States Air Force recruits. Cognitive performance on the Armed Services Vocational Aptitude Battery (ASVAB) were obtained from personnel selection records (no time of testing was available) and on the Cognitive Abilities Measurement-IV battery (between the hours of 0800 and 1200). The authors reported that ETs were higher in intelligence than MTs even when they were tested during the morning.
In addition to research examining M–E, there is some evidence that time-of-day may significantly alter psychological performance.

1.2. Time-of-day

According to Smith (1992), differences in performance on many tasks vary according to the time of day, and these variations may be related to the specific nature of the task. An interaction has been reported between M–E and time-of-day for cognitive tasks but not for perceptual-motor tasks (Monk & Leng, 1982), indicating that these may be important variables when considering performance on intelligence tests, although Matthews (1985) suggests that the effect of arousal on performance is also dependent on extraversion-introversion and time-of-day. This is supported by previous research indicating that there is a relationship between intelligence test performance, extraversion and arousal (Revelle, Amaral & Turriiff, 1976; Gilliland, 1980; Revelle, Humphreys, Simon & Gilliland, 1980).

Gupta (1991) has more recently reported that performance on the Cattell Culture Fair Intelligence Test (CFIT), a test of fluid abilities, was significantly modified by time-of-day, so that performance later in the day (1900 h) was better than earlier in the day (0900 h and 1400 h). However, for the Topology subtest of the CFIT, which assessed the ability to extract existing relationships and to apply them to new materials, performance was not modified by time-of-day.

If Gupta’s (1991) study can be replicated, significant changes to intellectual assessment procedures may be required. Intellectual assessment, to be valid, may need to be conducted with the knowledge of the effects of time-of-day on cognitive performance. There is also other research indicating that time-of-day may significantly influence performance on different cognitive tests (Laird, 1925; Folkard, 1975).

Other studies have reported that Short Term Memory (STM) performance, as opposed to Long Term Memory (LTM), declines throughout the day (Folkard & Monk, 1980). Performance rapidly deteriorates for Digit Span (DS) as the day progresses. Blake (1967) suggested that the negative correlation between level of arousal and STM necessary for DS performance might account for this deterioration. Variability in STM may therefore influence performance on intelligence tests requiring STM. According to Folkard, Knauth, Monk and Rutenfranz (1976), the importance of STM in task performance overshadows that of circadian variation in performance.

In relation to M–E types, memory efficiency of MTs has been observed to decrease over the day while memory efficiency of ETs increased (Lancry, 1986). Although there was no discussion of what this memory efficiency might constitute, the authors indicated that further research is required to examine the relationship between M–E types and a more comprehensive battery of memory tests such as the Wechsler Memory Scale (WMS), which is widely regarded as a useful clinical neuropsychological test (Lezak, 1995).

Payne (1989) has examined the effect of time-of-day on performance on a paced mirror-tracking task which, according to the investigator, involves STM. Time-of-day was suggested as a confounding variable, since random assignment of participants was not possible in the study. Payne suggested that participant recruitment might be influenced by M–E type, so that some participants are more motivated by participating at different times of the day. Indeed
subsequent research has shown that extraverts, who tended to be more active in the evening (and who also are more likely to be ETs) were found to choose to engage in evening activities (Wilson, 1990).

Other tasks which are cognitively under-stimulating such as serial reaction, vigilance, card sorting, letter cancellation and calculation tasks, may be sensitive to the level of motivation or degree of arousal, which in turn may be influenced by time-of-day. Performance on such tasks has been reported to vary over the day (Blake, 1967), but tasks such as binary discrimination did not (Craig, 1979).

While the effect of time-of-day has been generally accepted as an important factor in psychological research, very few studies have included it. Payne (1989) reviewed 467 experiments and found only 3% of these making explicit reference to time-of-day. This lack of emphasis on time-of-day by previous researchers is also reflected in the lack of information in test manuals on the optimal time for administering psychological tests. Finger’s (1982) review of the implication of circadian rhythms for psychology concluded with a warning that serious flaws and limited generality of research findings might be a real risk if the time-of-day factor was ignored.

In short, there is good evidence that time-of-day modifies performance in many different psychological tasks, particularly tests involving memory, although the specific effects of time-of-day or M–E types has yet to be adequately defined in any precise manner that might guide psychologists in psychological assessment.

1.3. Arousal

A physiological model explaining the effects of M–E and time-of-day on psychological performance may be derived from studies examining the role of arousal on psychological performance. According to Eysenck (1983) the effect of time-of-day, as well as intense noise, sleep deprivation, introversion-extraversion and incentives on performance are mediated by ‘arousal’. Eysenck broadly defines arousal as the psychological state of activation. The effect of arousal on memory is important to note because high arousal has previously been observed to impair the retrieval of relatively inaccessible information (Eysenck, 1983). Therefore, being highly motivated to retrieve information may deleteriously affect performance. Eysenck also concluded speculatively that the effect of anxiety-based arousal on information retrieval was stronger than that of effort-produced arousal.

Consonant with the ‘inverted U’ relationship between efficiency and arousal, greater arousal may facilitate information processing and decision making at the input level. At the processing level, a low level of arousal may result in insufficient activity to cope with the information, and too high a level may lead to too much ‘noise’ for efficient processing. At the output level, high arousal may lead to tenseness and therefore, to inaccurate responding (Singleton, 1989).

The effect of arousal also includes an increase in attention selectivity, disruption of some of the more complex and demanding processing strategies, and improved LTM relative to STM (Eysenck, 1983). Some support for this theory has derived from reports that increasing arousal over the day, as indexed by body temperature, impairs STM (Craik & Blankstein, 1975; Folkard & Monk, 1980; Holding & Nally, 1988).

Electrodermal measures of arousal have also been reported to be related to M–E types
Wilson, 1990). MTs were higher in arousal in the morning and ETs were higher in the evening. Wilson, consistent with the results reported by Tankova et al. (1994), has also concluded that the M–E dimension was more powerful in influencing the diurnal cycle than personality dimensions and, in this case specifically, diurnal cycles of arousal. Arousal theory has nevertheless been rejected as a complete explanation for the diurnal variation because it appears that there are other interacting endogenous rhythms that affect performance at different times of the day (Smith, 1992).

‘Synchrony effect’ has been described in relation to arousal, where performance on cognitive tasks has been shown to be optimal when testing times coincided with peak arousal periods (May, Hasher, & Stoltzfus, 1993). Although this synchrony effect may not affect the performance on all cognitive tasks, it has been shown to alter processes such as inhibitory control over thought, memory and even stereotypic judgments (May & Hasher, 1998; May et al., 1993; Bodenhausen, 1990; Petros, Beckwith & Anderson, 1990). In relation to M–E, MTs were found to peak in their arousal in the morning whilst ETs peak in the afternoon (May et al., 1993).

1.4. Aims

The relationship between M–E, time-of-day and intellectual performance is the focus of the present research. It is hypothesised that performance on the cognitive tasks (MAB and IT) will vary at different times of the day, and that this variation will also be influenced by M–E. Specifically, it is hypothesised that MTs will perform better on IT and the MAB Performance subtests in the morning than in the late afternoon, and that conversely ETs will perform better on these tasks in the late afternoon than in the morning. It is hypothesised IT and MAB subtests will be correlated negatively, confirming previous research. We included IT in order to examine the possible effect of time-of-day on this measure and on the relationship between IT and intelligence.

These are important research questions to address because if a relationship exists between M–E and performance on psychological tests at different times of the day, then for a valid and ‘fair’ assessment of cognitive ability, a knowledge of an individual’s M–E position is required. For example, assessing a MT in the afternoon or evening may significantly underestimate cognitive ability. Likewise, the cognitive assessment of an ET during a morning session may also represent an underestimate of optimal performance. In terms of work performance, a MT may be better suited to work in the morning than in the afternoon, and this may have important considerations for industries employing different work shifts or workers using flexible working hours. Thus, it is essential that research determine, whether a relationship exists between M–E and cognitive testing at different times of the day.

2. Method

2.1. Subjects

Twenty male and 50 female first-year psychology students participated with a mean age of
24.9 years (SD=8.3). The research was approved by the Swinburne University Human Research Ethics Committee, and all participants provided informed consent.

2.2. Materials and procedure

The 19-item Horne-Östberg (1976) Morningness–Eveningness Questionnaire (MEQ) was administered to all participants. Subjects participated on a voluntary basis, by filling out the Morningness–Eveningness Questionnaire and attending both a 0900 and 1500 testing session in which the MAB and IT tasks were administered. Participants were categorised into one of two groups depending upon their M–E score. Subjects with M–E scores between 16 and 47 were classified as evening-types (ETs) and those with scores between 48 and 86 were classified as morning types (MTs), reflecting the mean distribution of MEQ scores. They were further separated into two groups in order to counterbalance the order of time-of-day the tests were administered.

2.3. Inspection time

The IT procedure has been described previously (Deary & Stough, 1996). Instructions for the IT task emphasized that the procedure involved accurate, not rapid responding. Participants were told that the task involved simple visual discriminations in which they were required to judge which one of two lines was the shorter. A cue was presented for 500 ms prior to the stimulus onset. The stimulus consisted of two parallel vertical lines 24 mm and 34 mm long separated by 10 mm. Participants were required to respond by pressing a left key if the shorter of the two lines appeared on the left side and a right key if the shorter line appeared on the right side. The shorter line had equal probability of occurrence on the left or right side of the long line. The two lines were joined by a horizontal bar across the top of each line. Following the presentation of the cue, the stimulus was presented for a variable duration, ranging from 16 ms to 240 ms and then followed by the mask that was presented for 360 ms. The inter-stimulus interval was varied by each subject as the next trial would only proceed after the subject pressed a button. However, the time between the preceding response and the onset of the cue for the next trial was 2000 ms. Participants were instructed to respond as accurately as possible. Participants were given 10 practice trials at both 200 and 100 ms stimulus duration. A PEST procedure (Taylor & Creelman, 1967) was used to vary stimulus duration across trials and subsequently to determine each subject’s IT score (i.e. stimulus duration required for 80% responding accuracy). The initial stimulus duration was 144 ms for all participants and eight reversals were required before an IT estimate could be made. The stimuli and mask were presented via a high resolution 486 notebook computer which also registered responses made by pressing one of two buttons for either left or right, under the index finger of both hands.

2.4. Multidimensional Aptitude Battery (MAB).

The performance subtests of the MAB consisting of Digit Symbol (DS), Picture Completion (PC), Spatial (SP), Picture Arrangement (PA) and Object Assembly (OA) were administered.
The MAB is a group administered version of the Revised Wechsler Adult Intelligence Scale (WAIS-R) and validity studies have indicated high correlations between MAB and WAIS-R subtests (Jackson, 1984). In order to minimize practice effects from repeated administration of the same MAB items, odd and even numbered trials of all the MAB subtests were administered at either the 0900 or 1500 testing sessions, so that the administration of even and odd trials were balanced across subjects and testing time.

2.5. Temperature

Temperature was measured using a clinical thermometer under the arm of each participant at both the 0900 and 1500 testing sessions, after the administration of the tests.

3. Results and discussion

3.1. Morningness–Eveningness and cognitive ability

Table 1 reports the means and standard deviations (SDs) of all variables for MTs and ETs at the 0900 and 1500 testing sessions.

A doubly multivariate repeated measure statistics was performed. The between-subject factor being M–E (2 levels), and the within-subject factor is the time-of-day (2 levels). The result indicated that MTs and ETs did not differ significantly in their performance scores in all MAB subtests, their IT and body temperature ($F(7,62)=0.56$, ns) and their scores in all the measurements in the morning did not differ significantly from that in the afternoon ($F(7,62)=0.36$, ns), contrary to what was expected. More importantly, the multivariate interaction between M–E type and time of testing was not significant ($F(7,62)=0.59$, ns).

The results of the present study indicate that there is no reliable relationship between M–E and performance on cognitive tests at different times of the day, particularly comparing morning with late afternoon testing sessions. Thus, the present results indicate that valid

<table>
<thead>
<tr>
<th></th>
<th>MT</th>
<th>ET</th>
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<tbody>
<tr>
<td></td>
<td>0900 h</td>
<td>1500 h</td>
</tr>
<tr>
<td>IT</td>
<td>37.1 (11.1)</td>
<td>35.6 (11.2)</td>
</tr>
<tr>
<td>Digit symbol</td>
<td>11.1 (2.3)</td>
<td>11.0 (2.3)</td>
</tr>
<tr>
<td>Picture completion</td>
<td>10.2 (3.0)</td>
<td>10.8 (2.6)</td>
</tr>
<tr>
<td>Spatial</td>
<td>14.6 (4.6)</td>
<td>15.0 (4.1)</td>
</tr>
<tr>
<td>Picture arrangement</td>
<td>4.9 (1.8)</td>
<td>5.1 (2.0)</td>
</tr>
<tr>
<td>Object assembly</td>
<td>7.1 (2.4)</td>
<td>7.1 (1.8)</td>
</tr>
<tr>
<td>Temperature</td>
<td>36.1 (0.9)</td>
<td>36.2 (0.8)</td>
</tr>
</tbody>
</table>
assessments of cognitive abilities using tests such as MAB does not require knowledge of M–E and of optimal time-of-day for each individual.

As this is an exploratory study, we decided to also examine univariate tests. The results indicated that performance in PC was better in the afternoon than in the morning \((F(1,68)=3.84, P < 0.05, \text{one-tailed})\), and as expected, body temperature in the afternoon was higher than that in the morning \((F(1,68)=3.07, P < 0.05, \text{one-tailed})\). Also, there was an interaction between time-of-day and M–E type in SP subtest performance \((F(1,68)=3.46, P < 0.05, \text{one-tailed})\) although the interaction was in the opposite direction to what was expected. It was expected that MTs would perform better in the morning, and ETs to perform better in the afternoon.

Performance in the afternoon may have been masked by ‘post lunch dip’ which has been observed by previous researchers. Following the dip, Payne (1989) observed a clear, sharp recovery at 1400 h that was attributed to meal intake when blood sugar concentration rose and the brain, as a consequence, increased its glucose intake.

Wilson (1990) observed that there were two exceptions to the general trend of MTs to be higher in arousal in the morning, one of which was the ‘post-lunch dip’. The other, which is of interest here, is that ETs reportedly wake up with ‘something of a “start”, as though the experience is disturbing’ (Wilson, 1990). ETs’ arousal then decreases to a low point around 1000 h, which is the time the participants completed the morning test sessions in the present study. Recently, Roberts and Kyllonen (1999) also reported that ETs are more likely to perform well on tests for memory, and processing speed even if they are tested in the morning. However the reason why only SP subtest was affected remains unknown.

3.2. Time-of-day effects

The present study did not support the findings of Gupta (1991) that performance on intelligence tests improved over the day.

All subtests of the MAB correlated with IT in the expected direction (negative) although not all correlations reached a level of statistical significance. The direction of the correlation confirmed previous findings in other studies. From the data, it would appear that IT correlated significantly with more MAB subtests in the afternoon than in the morning. This could be due to the level of arousal. Recently, Stough et al. (1996), and Stough and Bates (2000) have argued that performance on intelligence tests is influenced by both the level of arousal and level of extraversion. The present hypothesis may be consistent with this view.

3.3. Temperature, MAB, and IT

Correlations between IT (measured at 0900 and at 1500 h) and MAB Performance subtests (measured at 0900 and 1500 h) are reported in Table 2. On the whole, significant correlations between IT and MAB Performance subtests were only observed for IT and MAB measured at the 1500 h session. Only correlations between DS (measured at 0900 and 1500 h) and IT (measured at 0900 and 1500 h) were significant (DS measured at 1500 h approached significance \(P = 0.05\)). Correlations between IT measured at 0900 h and all other MAB Performance subtests measured at either 0900 or 1500 h were not significant. Correlations
between IT measured at 1500 h and all other MAB Performance subtests measured at 1500 h were significant, although somewhat lower in magnitude than correlations normally reported between IT and IQ test subtests (see Nettelbeck, 1987 or Deary & Stough, 1996 for a review).

The pattern of correlations reported in Table 2 indicate that afternoon testing sessions may be optimal for assessing the relationship between IT and IQ. However, future research is required to more adequately examine this relationship. A mechanism for this relationship is difficult to propose given that temperature, MAB Performance subtests and IT did not significantly differ across the testing sessions. The correlations between ITs and temperature measures were not significant. In addition, there was no significant difference in variability of either IT or MAB Performance subtests across the two testing sessions. IT correlated significantly only with DS in the morning, but correlated significantly with four of the five subtests in the afternoon. These differences in the level of significance of correlations may be related to the critique made by Deary and Stough (1996). They commented that the stability of IT measure has not been established, and factors that might influence the change of IT over time has also not been adequately explained by Vickers, Nettelbeck and Willson's (1972) original theoretical model of IT. It is possible that IT taps some cognitive or perceptual process that differs over time. Nonetheless, consistent with previous studies validating IT as an important measure of intelligence, IT correlated negatively with all MAB subtests.

Table 3 reports correlations between temperature measured at 0900 and 1500 h and between MAB Performance subtests measured at 0900 and 1500 h Significant or near significant

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### Table 2

Correlations between IT and MAB performance subtests at 0900 and 1500 h

<table>
<thead>
<tr>
<th></th>
<th>DS</th>
<th>PC</th>
<th>SP</th>
<th>PA</th>
<th>OA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0900 h testing session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT 0900 h</td>
<td>-0.28*</td>
<td>-0.09</td>
<td>-0.21</td>
<td>-0.01</td>
<td>-0.16</td>
</tr>
<tr>
<td>IT 1500 h</td>
<td>-0.25*</td>
<td>-0.15</td>
<td>-0.20</td>
<td>-0.21</td>
<td>-0.05</td>
</tr>
<tr>
<td><strong>1500 h testing session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT 0900 h</td>
<td>-0.27*</td>
<td>-0.17</td>
<td>-0.10</td>
<td>-0.06</td>
<td>-0.17</td>
</tr>
<tr>
<td>IT 1500 h</td>
<td>-0.22</td>
<td>-0.29*</td>
<td>-0.36**</td>
<td>-0.34**</td>
<td>-0.30*</td>
</tr>
</tbody>
</table>

* NB: *P < 0.05, **P < 0.01.

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### Table 3

Correlations between MAB performance subtests at 0900 and 1500 h and temperature measured at 0900 and 1500 h

<table>
<thead>
<tr>
<th></th>
<th>DS</th>
<th>PC</th>
<th>SP</th>
<th>PA</th>
<th>OA</th>
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</thead>
<tbody>
<tr>
<td><strong>0900 h testing session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp (0900 h)</td>
<td>-0.24*</td>
<td>-0.08</td>
<td>-0.16</td>
<td>-0.28*</td>
<td>-0.22</td>
</tr>
<tr>
<td>Temp (0300 h)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.08</td>
<td>-0.17</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>1500 h testing session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp (0900 h)</td>
<td>-0.27*</td>
<td>-0.06</td>
<td>-0.21</td>
<td>-0.20</td>
<td>-0.21</td>
</tr>
<tr>
<td>Temp (1500 h)</td>
<td>-0.09</td>
<td>0.22</td>
<td>-0.02</td>
<td>-0.08</td>
<td>-0.06</td>
</tr>
</tbody>
</table>

* NB: *P < 0.05.
correlations ($P = 0.06$) were obtained between temperature measured at 0900 h and MAB Performance subtests measured at both 0900 and 1500 h testing sessions. Out of the 10 possible correlations between temperature measured at 0900 h and MAB Performance subtests measured at either 0900 or 1500 h, three were significant at the 0.05 level, four approached significance ($P = 0.05$ or $P = 0.06$) and all were negative indicating that increasing temperature was associated with decreasing scores on the MAB Performance subtests. Again these correlations are difficult to explain theoretically. Speculatively, these results indicate that high and low MAB performance may be influenced by body temperature measured in the morning. Thus subjects with high MAB performance ability recorded lower body temperatures at 0900 h than low MAB ability subjects. This result may be a result of the less effort required by high ability subjects in performing this task. However this explanation does not explain why such a pattern of correlations was not also observed in the 1500 h testing session.

In conclusion, the results of the present experiment taken on the whole indicate that contrary to previous research, intellectual performance is not related to either M–E or time-of-day.

Acknowledgements

The authors would like to thank Dr Alex Sergejew for his comments on an earlier version of this manuscript.

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