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Time-of-Day Effects on Human Performance

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REVIEW OF RESEARCH

TIME-OF-DAY EFFECTS ON HUMAN PERFORMANCE

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The course of study of time-of-day effects on human performance has not been an easy one to chart, with many findings that seem to be in opposition. This review examines the difference between group and individual differences with regard to time-of-day effects; time-of-day effects in individuals; morningness-eveningness as an individual characteristic; morningness-eveningness in adolescents; effect of time of day on cognition and academic performance; time-of-day effects on intelligence, testing, and academic achievement; the effect of matching individuals to their preferred time on academic achievement; and motivation as a primary confounding variable in time-of-day preference/academic performance studies. Other possible confounding variables and procedures in testing time-of-day effects are also briefly examined.

The course of study of time-of-day effects on human performance has not been an easy one to chart, with many findings that seem to be in opposition. Some researchers have found that performance increases across the day; some have found that it decreases across the day; some have found that it increases to a midpoint, after which it decreases. Through all the studies, factors such as motivation, psychological characteristics, and physical state of the individual serve only to confuse the picture.

In most of these studies, researchers were intent on studying differences that might be common to groups. The term *group difference* refers to characteristics that are attributable to group membership, while *individual differences* are attributes particular to no defined group. Therefore, while individuals may share characteristics that also are shared by a group, the characteristics are not present because of membership in that group. If, for example, researchers discover that males consistently perform a certain task better in the morning than at other times of day, that performance characteristic is most likely a group difference, even though some females may also perform the task better in the morning. For females who perform better in the morning, the performance characteristic is an individual difference. The origin of group and individual differences, as might be expected, is a very complex field of study that will not

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be addressed here. The reader is invited to consult the work of Eysenck (1994) and Eysenck and Eysenck (1985) for possible biological foundations of individual differences that are responsible for sensitivities of individuals to their environments. Thus, individual differences are most likely an interplay of both biology and environment.

Little research into individual differences in time-of-day effects on performance has been conducted, most likely because, as mentioned earlier, researchers are more interested in findings that may be generalized to large groups of people. However, in practical, applied terms, the study of individual differences becomes key. When a physician elects to prescribe medication to a patient, for instance, knowing how that particular patient functions is essential. Educational services need to be prescribed in much the same way, with the individual assessed for such characteristics as motivation, personality characteristics, and skill levels. An individual difference that is proving to be significant in many current studies in a variety of fields is that of time-of-day preference. Although the term *preference* implies choice on the part of the individual, studies are beginning to validate the stand that several factors, many physiological and beyond the control of the individual, are combining to make time of day a defining element in performance.

The implications for education that emanate from such studies are enormous, widespread, and address such questions as these: If time of day is a significant factor in the performance of students and teachers, should schools attempt to match preferred time of day to tasks of both students and teachers? Should students and teachers schedule their most difficult subjects at their preferred time of day? Should schools change their schedules to accommodate time-of-day preferences if they appear in large percentages of their student population? Would schools be able to make such changes, given the current budget woes of most systems?

TIME-OF-DAY EFFECTS IN INDIVIDUALS

Although a number of circadian oscillators are in place within humans, the key word with regard to these seems to be flexibility (Webb & Agnew, 1978); humans are able to override such biological circadian cues as light or core body temperature if their schedules demand it. After all, humans constantly change their bedtime and waking time to match environmental, behavioral, or social cues (Campbell, 1992); in other words, most people find it easy to remain awake for social interaction on weekends, and individuals on day shifts are resigned to arising at an early hour to meet the demands of their employers. This ability to override possible circadian influence might be viewed as a state-or-trait question: that is, is variability in individual performance in itself an individual difference? A study (Rabbitt, Osman, Moore, & Stollery, 2001) showing exactly that tested 98 people weekly for 36 weeks. Simple letter cancellation tasks were used to show that, after circadian variability was controlled for, variability in performance both from trial-to-trial within a single session and variability in performance from day-to-day was predictable for individuals and varied inversely with intelligence test performance. This study suggests that those individuals with higher cognitive ability, as measured by traditional intelligence tests, are more able to override their own circadian influences, a phenomenon that is seen quite readily in school settings. Individuals who exhibit high ability levels can consistently do well on traditional measures of performance; as a result, other measures that correlate positively with intelligence measures, such as grade point average, reflect this quality. However, while this phenomenon is an interesting one, what also cannot be overlooked in the application of studies like this one is, of course, teacher expectation, which is not addressed in this review.

Many individual differences fall into the general category of another trait factor, personality, and some have been studied for time-of-day effects. One that has received extensive attention is impulsivity, which often manifests itself as making quick decisions and snap judgments, and acting without seeming to think at all. Those who exhibit high impulsivity also show great intraindividual differences on simple performance tasks, such as tapping (Barratt, 1963). Those individuals with high impulsivity scores exhibit significant time-of-day effects on tasks requiring high attention levels, such as letter cancellation and digit span forward, with a tendency for these individuals to perform better in the evening (Lawrence & Stanford, 1999). However, studies on attention have not definitively answered the question of whether time-of-day effects play a role in attention. Another study found that individual participants with high impulsivity scores demonstrated a consistently higher level of efficiency either in the morning or the afternoon (Guerrien, Leconte-Lambert, & Leconte, 1993). Therefore, the reason for the variation in the findings of so many studies might very well be that whether a person exhibiting impulsive characteristics performs better at one time of day or another is an individual, but consistent, difference; in other words, it is a difference that is difficult to find when one divides a sample into arbitrary groups for testing.

Previous research has suggested that highly impulsive individuals perform better in the evening than in the morning due to differences in their arousal rhythms when compared to others. Confirmation of these findings without external manipulation of arousal level was attempted in a study in which 40 volunteer participants (20 high impulsives and 20 low impulsives) completed the Barrett Impulsiveness Scale. The participants completed a variety of performance and cognitive tempo measures at two different times, once between 8:00 a.m. and 10:00 a.m. and once between 6:00 p.m. and 8:00 p.m. Results revealed no significant interaction between impulsivity and time of day. However, high impulsives showed greater variability in performance and faster cognitive tempo than low impulsives. Time-of-day differences were significant for tasks requiring attention, with all subjects performing better in the evening on those tasks (Lawrence & Stanford, 1999).

Introversion-extraversion is a somewhat polarized personality characteristic commonly referring to whether individuals tend to turn their thoughts and feelings inward toward themselves (introversion) or whether they are socially outgoing and enjoy interpersonal encounters (extraversion). The possibility also exists, then, that the aspect of personality that is responsible for the association between evening type and extraversion is sociability rather than impulsivity. This was the case in one study of 74 undergraduates (Larsen, 1985). It is possible that individuals who enjoy being around and participating in activities with others find that the opportunities for doing so are more frequent in the afternoon or evening; this interaction may lead to increased stimulation and arousal and subsequent improvement in performance on tasks. After a period, this increased arousal may become a conditioned response to the time of day rather than to the presence of others.

In other experiments (Colquhoun, 1960; Colquhoun & Corcoran, 1964), introverts performed better than extraverts in the morning. Little difference was found between the two groups in the afternoon. As an adjunct to the performance studies, a physiological study of skin conductance found that introverts were more highly aroused than extraverts across the span of the day, but that the difference was particularly pronounced in the morning; by midnight, the two groups had converged (Wilson, 1990). Again, sociability proved to be the aspect of the extraverted individual that was responsible for this phenomenon, rather than impulsiveness. If the performance of high impulsives tends to increase across the day, then indicators of impulsivity should not decrease, thus the assumption that another personality factor was behind this congruence of the arousal distribution of both types of individuals.

An interesting aside to the study of the performance of introverts and extraverts is that the testing situation is even more important than in studies of other personality traits (Blake, 1971; Colquhoun & Corcoran, 1964). The 1964 experiment by Colquhoun and Corcoran found that introverts performed better than extraverts only when they were tested in isolation, whereas the presence of other study participants improved the performance of the extraverts. Rather than a time-of-day effect, then, perhaps what these studies revealed was the influence of the presence of other study participants on performance. Indeed, one study (Revelle, Humphrey, Simon, & Gilliland, 1980) found that it was actually the impulsivity aspect of the extravert personality that was responsible for time-of-day differences when scores on a cognitive task rather than a simple performance task were used as the dependent variable.

MORNINGNESS-EVENINGNESS AS AN INDIVIDUAL CHARACTERISTIC

A personality characteristic that shows some biological correlates and that appears to correlate highly with many types of performance is morningness-eveningness. Morningness-eveningness is a concept which dates from the work of O'Shea (1900); however, systematic studies of the phenomenon did not begin until almost 4 decades later, when Freeman and Hovland (1934) and Kleitman (1939) began to do experiments which attempted to correlate such biological phenomenon as body temperature with a preferred arising or bed time.

The term *chronotype* refers to one's individual time-of-day preference. Morning chronotype individuals prefer arising early, and they often feel they do their best work before noon, while evening-type individuals prefer to sleep later. They would rather do their most difficult work later in the day. Morningness-eveningness is typically reported as a score on one of many versions of an instrument developed by Horne and Oestberg (1976), called, appropriately enough, the Morningness-Eveningness Questionnaire (MEQ). This self-report questionnaire has been translated into many languages and modified for many age groups; reliability and validity coefficients for most versions are quite high. By 1991, researchers had fairly well established that the core temperature of most morning people reached its peak earlier in the day than that of evening people (Blake & Corcoran, 1991), lending support for the argument that individual biological differences are responsible for this difference, rather than some unknown environmentally produced factor. A 1998 study (Hur, Bouchard, & Lykken) found that genetic variance was responsible for 51% of the variability in morningness-eveningness. These findings support that of Horne and Oestberg (1976), who found that morning types (as determined by the MEQ) reached their peak oral body temperature at about 7:30 p.m., while evening types did not peak until 8:40 p.m. This same study showed few significant differences between morning and what Horne and Oestberg term *neither* types for bedtime, peak performance time, or sleep length. Interestingly, all three groups exhibited no significant differences in number of minutes of sleep obtained. This becomes an important finding when the concept of morning, neither (termed *intermediate* or *neutral* by some researchers), and evening types is introduced into the academic arena. If evening types have a significantly later bedtime, but require the same number of minutes of sleep, when will that sleep come if evening-type students go to bed later than morning or intermediate types but are required to be at school at an early hour? Many subsequent researchers appear to interpret Horne and Oestberg's work as establishing a dichotomy; that is, an individual is either a morning type or an evening type. A closer look at the study (1976) in which they introduced their questionnaire reveals not only *definitely morning* and *definitely evening* types, but actually three other types as well: *moderately morning*, *neither*, and *moderately evening*. The morning type and the neither type share many commonalities: They prefer bedtimes close to 11:30 p.m. (11:26 p.m. and 11:30 p.m., respectively), while evening types in the study had a mean bedtime of 1:05 a.m. The mean arising time for morning types was 7:24 a.m., with 8:07 a.m. for intermediate types, a difference of 43 minutes. Evening types had a mean arising time of 9:18 a.m., almost 2 hours after morning types and over an hour later than intermediate types. True evening types, then, are markedly different from morning and intermediate types, and morningness-eveningness is more a continuum than a dichotomy. Variables that exhibit a continuum are not group differences by their very nature, although they are often categorized for research purposes.

In addition to Horne and Oestberg's work with the correlation of biological variables with morningness-eveningness, skin conductance studies continue to support a biological origin for morningness-eveningness. Skin conductance is a physiological measure of an individual's emotional state as evidenced by the amount of acetylcholine present in the sweat glands and, subsequently, the surface of the skin. This chemical is produced by the sympathetic nervous system in reaction to stress. One such study comprised 111 people, aged 16-60 years, who measured their own skin conductance hourly throughout a day; participants also kept a log of activities and drug intake. A primary finding was that self-reported morning types showed higher skin conductance in the morning, while evening types were higher in the evening, indicating a higher arousal level for morning types in the morning and evening types in the evening (Wilson, 1990), a finding consistent with the data on core body temperature from the other studies mentioned. Such a finding may also mean that motivation, one manifestation of arousal, in students may be higher in the morning for morning types and lower in the afternoon, while the opposite would be true for evening types.

However, morningness-eveningness is considered by some to be linked more to personality than to biology by its association with other personality traits that might precipitate social factors that affect the entrainment of the individual's circadian rhythms to the sleep-wake cycle. In a study of 120 male and 80 female undergraduates, aged 18-38 years, Horne and Oestberg's MEQ predicted circadian rhythms related to arousal and to depression (Matthews, 1988). This is not surprising, considering that arousal is correlated positively with body temperature and cortisol (the "fight-or-flight" hormone) with depression; both also correlate positively with the questionnaire.

So, while morningness-eveningness is frequently dichotomized in correlative studies, the fact remains that it is essentially an individual characteristic, as exhibited by the fact that in some studies which attempt to find group differences, an entire group of participants (those who score intermediate, neutral, or neither type on the morningness-eveningness continuum, depending on the instrument used) must be eliminated before any significant difference can be found. In most studies, definitely morning and moderately morning types are combined to form morning type, and definitely evening and moderately evening types are combined to form evening type. Apparently, the diagnosis of definitely morning type or definitely evening type is relatively rare. In addition, some researchers (Cofer et al., 1999) have found evidence that morningness-eveningness remains constant from childhood at least through college age and often beyond. Thus, extreme morningness or eveningness preferences may have their origins very early in the developmental life of the individual, perhaps even during the prenatal period. Since melatonin, the "sleep hormone" secreted by the pineal gland, is known to be secreted in breast milk, perhaps further research will be able to determine if mothers entrain their children as morning or evening types, according to the mother's own chronotype.

MORNINGNESS-EVENINGNESS IN ADOLESCENTS

Much of the current research into morningness-eveningness is being conducted with adolescents. To many people, adolescents, as a group, seem to prefer a late bedtime coupled with a late arising time. This phenomenon in adolescents began to be studied near the end of the 1970s; most researchers (Carskadon, 1990; Crouter & Larson, 1998; Wolfson, 1997) saw the phenomenon as purely social, following such psychosocial developmental models as that of Erikson. However, controlled studies (Carskadon, 1990) began to reveal that there might be a biological basis as well; adolescents displayed what Carskadon referred to as *delayed sleep phase onset*. If so, adolescents would experience a later onset of sleep with a desire to sleep later the next morning as well. In addition, many adolescents seemed to require more sleep than previously thought, some requiring more than 9 hours. Soon, studies (Carskadon, 1999) were being reported whose results implied that eveningness was not an individual difference but a group difference in adolescents.

Not all researchers agreed. One study (Callan, 1999) maintained that about 33% of high school students have no time-of-day preference, with about 20% (combined) favoring mornings and 30% (combined) favoring afternoons or evenings. That means over half of adolescents studied had either no preference or preferred mornings. A 1998 study (Intons-Peterson, Rocchi, West, McLellan, & Hackney) challenged Carskadon's studies by finding that 57% of the younger adults tested demonstrated no preference on the morningness-eveningness questionnaire. Only 6% tested as definitely evening types. In the older adult participants, 93% tested as definitely morning, moderately morning, or no preference, which supports the hypothesis of other researchers (Tune, 1969; Webb, 1982) that individuals' time-of-day preference changes across the lifespan. In this match-mismatch study, participants were tested at both their preferred times and their non-preferred times. Both groups performed significantly better on a memory test at their preferred times. Moreover, the older group performed as well as the younger group when both groups were matched to their preferred times, a finding that refutes the idea that memory must diminish in older adults. As the authors note, their findings in both these studies bring up the question of whether testing of age-related differences in performance has compromised the testing of older adults, since such testing, according to gerontologists interviewed by these researchers, is most often conducted during afternoon hours. Even when participants are allowed to select their own time for testing, the times offered are still those selected by the researcher, who is often a younger person.

A follow-up to the 1998 study, done in 1999, used the MEQ to determine if recall memory differed from recognition memory in matched and mismatched groups. Seventy-seven college students (mean age = 20) were tested, along with 42 older adults (mean age = 72). After results of the questionnaire were obtained, the participants were randomly assigned to one of two groups, optimal or non-optimal. The optimal group members were tested at their preferred time, no matter when that time was (morning or afternoon). The non-optimal group members were tested at their non-preferred time. Only the older adults who were tested at their non-preferred time showed consistently poorer performance. The younger group performed better on the recall task. No significant differences were found between the age groups on the recognition memory task. Again, older adults performed at the same level as younger adults when matched to their preferred times; younger adults performed well at all times (Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1999).

The findings of these two studies do not mean, however, that these are necessarily group differences; in fact, both of these studies cautioned that many other researchers have found “substantial individual differences” (Intons-Peterson et al., 1999, p. 32) in age-related time-of-day preferences. However, the findings do indicate the certainty that changes of many types occur across the lifespan and that for many individuals, working at their preferred time results in optimal performance.

EFFECT OF TIME OF DAY ON COGNITION AND ACADEMIC PERFORMANCE

For both psychology and education, research into the effects of time of day upon performance remains pertinent. This is especially true in light of educational psychology’s attempt to improve the quality of education on both group and individual levels. Circadian variation averages about 20% of the variance in laboratory studies of cognitive performance and 40% in field studies (Kelly, 1996), which certainly earns the factor consideration in models of cognitive performance. This average was confirmed in a study (Gillooly, Smolensky, Albright, & His, 1990) of 12 male participants in which the day/night variation in performance over all cognitive tests accounted for 21% of the 24-hour mean. Research into time-of-day effects on cognition has emphasized the following areas: time-of-day effects on attention, alertness, and vigilance; effects on level of performance depending on task type and duration; operational efficiency (speed versus accuracy); and effects on intelligence, testing, and academic achievement.

The simplest types of cognitive tests are those attempting to measure arousal level, attention, or vigilance; sometimes the term *alertness* is used. Many of these tests involve a letter cancellation or notation exercise in which the participant is instructed to cross out a certain letter each time it occurs in a given passage. Alternatively, he or she may be asked to mark each time a letter appears twice consecutively; perhaps the participant may be asked to push a button each time a flash of light or a particular number or sequence of letters or numbers appears on a screen. Whatever the task, the object is to retrieve a score that would indicate the degree to which the participant can attend to a task and still maintain accuracy and speed. Of course, many individual factors are involved, such as practice effect or motivation. However, many studies have been able to determine the likelihood that results are the effect, at least in part, of the time of day.

Vigilance in 30 Indian youngsters, aged 10-16 years, was examined with a paper-pencil cancellation test administered at three different times of the day: 9:00 a.m., 2:00 p.m., and 6:00 p.m. The children were tested at school in separate rooms. A 2 x 3 factorial design was employed with gender as one factor and time of day the other. Results were that cancellation speed was higher in the morning than in the evening and afternoon, with the greatest frequency of errors in the afternoon as well. The only significant interaction effect for gender and time of day was in omission errors; girls committed fewer errors than boys at the 9:00 a.m. and 2:00 p.m. testings, but not at the 6:00 p.m. testing. The researchers (Rana, Rishi, & Sinha, 1996) concluded that the decline in vigilance performance is greatest in the afternoon, followed by the evening. They also noted that their findings were in disagreement with those of Colquhoun (1971), Blake (1967), and Gupta (1991), all of which are detailed in other sections of this review. They accounted for these differences by postulating that "mental vigor and receptivity" (p. 13) may decline as the day progresses.

Several cognitive task features were studied in three experiments (Craig, Davies, & Matthews, 1987), all of which were ultimately concerned with vigilance performance. In the first, participants detected differing events and frequency of signals. Lowering of signal frequency resulted in decreased performance, especially in the afternoon, which would indicate a lessening in vigilance across the day. In the second, a rapid discrimination task was used, and in the third, an unpaced discrimination task was paired with another stimulus event. Findings for the 93 adult participants were that efficiency declined across the time of the experiments, while speed increased. These declines in efficiency were more apparent in the afternoon, although the ability to perceive stimuli was lower in the morning.

Rodgers and Holding (1991) attempted to partition performance efficiency trends from strategy or changes in speed in a study of 12 male students. The students were asked to perform three tasks simultaneously, with manipulation of test requirements. The men were tested six times between 8:00 a.m. and 11:00 p.m. Performance curves differed for the varying combinations of tasks, but findings for all combinations indicated that efficiency fell during the morning hours but improved later in the day.

Almost the same results were found in another study (Bhattacharya & Tripathi, 1989) of 24 male graduate students. The researchers conducted flicker fusion tests, reaction time, forward and backward memory, and associative recall. Flicker fusion refers to testing in which participants are asked to discern the point at which two flickering lights appear to be a continuum of light. Forward and backward memory is commonly referred to in psychological testing as digit span; the participant is asked to repeat increasing series of numbers; initially, a sequence is repeated exactly as the examiner states it; a second test is administered in which the examinee is asked to repeat another, different sequence in reverse order to that given. Testing was done on 2 consecutive days, once each morning and once each evening. Data analysis again revealed superior evening performance on reaction time and backward memory; however, associative recall (a short-term memory task; see below) was better in the morning. No significance was found for flicker fusion.

In a match-mismatch, short-term memory task study, 40 morning- and 39 evening-type females participated in a memory test involving recall of prose passages of two different difficulty levels. As expected, recall decreased across the day for the morning types, while it increased for the evening types. Time-of-day effects were greatest for highly important ideas from difficult passages; the researchers concluded that time of day influences immediate recall of prose, with the effects dependent on the chronotype (morning- versus evening-type) of the individual (Petros, Beckwith, & Anderson, 1990).

Similar results were found in another study in which 34 college students and staff were tested in the morning and 30 in the afternoon for memory of text. They hypothesized that the exact wording of the text would be better recalled in the morning, while meaning of the text would be remembered better in the afternoon. Findings showed that those participants tested in the morning did indeed recall exact wording better than those tested in the afternoon; however, the hypothesis that memory for meaning only in the afternoon was not supported. One conclusion was that meaning was more likely to be remembered than exact wording at both times of day. However, the meaning is more easily supported by verbatim text recall in the morning than in the afternoon (Oakhill & Davies, 1989).

An alternative explanation for the *synchrony effect*, the concept that individuals exhibit peak performance periods, is that the modulating effects of time of day on age differences may be related to deficits in attentional resources (Chelminski, 2000). In a study of 48 young college students and 45 elderly adults, participants were tested individually on a prose-recall task and a garden-path task that was designed to assess inhibitory control over no-longer-relevant material in a divided-attention condition. Significant differences were found for young adults compared to older adults in prose recall, reading time, and reaction time. No evidence of a peak performance period was found.

A more interesting result of the study, though, may be that differences in cognitive performance tasks are more a function of the *nature* of the task and the *resources* upon which the task draws. Functions involving semantic knowledge or other *crystallized* abilities, such as the ability to use multiplication tables, are often unaffected by time of day, whereas *fluid* abilities, such as using logic to solve a problem, are (May & Hasher, 1998). These crystallized abilities are not only very well learned; they are also continually practiced. Fluid abilities change because the process used changes with each situation in which the abilities are used. In addition, crystallized abilities are often formally learned; fluid abilities are largely the result of casual or trial-and-error learning.

To determine whether cognitive performance in adults was influenced by time of day, 50 males and 54 females, all undergraduates or support staff of a university and all fairly highly educated (from 12.88 years to 15.35 years of education) engaged in a vocabulary test (crystallized abilities), a verbal-fluency test (both crystallized and fluid abilities) and a trail-making test (fluid abilities). All were tested at a time of convenience between 8:30 a.m. and 5:30 p.m. Pearson correlations revealed no significant correlation between the two independent variables, time of day and age (Brown, Goddard, Lahar, & Mosley, 1999). Results indicated that neither time of day nor age was predictive of scores on the vocabulary test; on the verbal-fluency test, age proved to account for 9% of the variance, with time of day contributing only 2%. Finally, on the trail-making test, almost 30% of the variance was accounted for by both independent variables, but age accounted for over 29%.

These results caused the researchers to conclude that time of day does not exert a significant influence on adult cognitive performance. However, this study did not provide any means to determine preferred times for the participants, nor did the researchers make any attempt to test participants at their preferred times. This study indicated, then, that age is definitely helpful as a predictor of cognitive performance, but time of day in adults is not. It is tempting to deduce, then, that some other age-related factor is at work in determining performance after adolescence and young adulthood, but that factor is not a function of light, core body temperature, arousal levels, or other factors that reflect time-of-day effects.

In a brief review of some other pertinent studies, Baddeley, Hatter, Scott, and Snashall (1970) found that immediate memory for digits was better in the morning; Folkard and Monk (1978) found that long-term memory was superior for material learned in the afternoon, and Furnham and Rawles (1988), after testing 104 male recruits, aged 18-24 years, to a training school, concluded that spatial ability was better in the morning than at noon or in the evening. However, it must be noted that Furnham and Rawles' study was not a test-retest design; the 104 participants were divided into three groups.

TIME-OF-DAY EFFECTS ON INTELLIGENCE, TESTING, AND ACADEMIC ACHIEVEMENT

In a study of time-of-day effects on intelligence, the scores of 34 matched pairs of children, aged 6 to nearly 16 years, on the Wechsler Intelligence Scale for Children—Revised (WISC-R) were compared. Verbal, Performance, and Full Scale IQ scales were used. No significant differences were found between morning and afternoon testing, although performance on the Verbal and Full Scale IQ measures varied more during the morning testing (Leigh & Reynolds, 1982). Again, this may indicate more of a time-of-day effect on crystallized abilities, rather than fluid abilities, if we make the assumption that the variation in the verbal portion was also responsible for the variation in the Full Scale IQ. The verbal portion of this test consists almost entirely of learned knowledge and tests crystallized abilities, while the performance portion relies more on the ability to make associations and logical deductions and therefore tests fluid abilities.

A more homogeneously older group was used in a study of 64 high school student volunteers who were administered subtests of the Wechsler Intelligence Scale for Children—Third Edition (WISC-3). These subtests, the Verbal Scale IQ and Processing Speed factors, were given both in the morning and in the afternoon. Time-of-day preference for the students was determined by a questionnaire, and body temperature was recorded at testing times. Significant three-way interactions were found for Verbal IQ, Verbal Comprehension, and Processing Speed factors among time of day, time-of-day preference, and first versus second test administration; a two-way interaction was found for Processing Speed between time of day and time-of-day preference. Participants who reported themselves as morning types on the questionnaire had higher temperatures in the morning, compared to those who rated themselves as evening types (Altabet, 1995). This finding supports the research of Blake and Corcoran (1991), as described above. An additional study on older students, this time on 60 female Hindi college students, was conducted by administering the Eysenck Personality Inventory and the IPAT (Institute for Personality and Ability Testing, Inc.) Culture Fair Intelligence Scales. Analysis of the data revealed that intelligence test performance was better in the evening than the morning, except for one subtest. Personality had no effect on intelligence test performance, nor was there an interaction between personality and time of day for intelligence test performance (Gupta, 1991). These three studies, along with much of the other study on time-of-day effects in adolescents and young adults, suggest that time of day may have an effect on intelligence test performance once the individual reaches puberty. Although intelligence is commonly viewed as a more or less static indicator of the individual's cognitive capacity, its quantification may vary. Does this mean that intelligence itself varies? Further research may indicate that those components that make up intelligence fluctuate more than was thought in the past.

THE EFFECT OF MATCHING INDIVIDUALS TO THEIR PREFERRED TIME ON ACADEMIC ACHIEVEMENT

Some evidence now exists, however, that supports the notion that academic achievement can be improved if *individuals* are matched to their preferred learning times. In a 1979 study, students having difficulties in mathematics and who preferred learning in the afternoon, but who had been scheduled into morning mathematics classes, were able to turn their achievement in mathematics toward a significantly more positive trend when they were rescheduled into afternoon classes (Carruthers & Young, 1979). Motivation and discipline were two other variables considered in this study, so it was unclear whether improvement could be attributed to an improvement in the students' actual ability to comprehend and apply concepts, or whether increased motivation or better behavior led to the improvement. In another study involving matching individual secondary students' time preferences (Lynch, 1981), truancy rates declined even in students with chronic truancy. In the lower grades, a study revealed that gains in achievement in both mathematics and reading resulted from matching students to their preferred learning times for those subjects. In that study, 286 children in grades 3 through 6 were either matched or mismatched to their time preferences for learning in mathematics and reading classes. Students were followed for a 2-year period, with each student matched to his or her time preference twice and mismatched twice across four semesters. Results showed that more than 98% of the students achieved statistically significantly higher scores when taught at the best time for them and did worse when taught at the nonpreferred time (Virostko, 1983).

Finally, a study examining teacher in-services aimed at teaching innovative teaching techniques resulted in increased occurrences of implementation of the strategies learned when conducted at teachers' preferred times (Freeley, 1984). A word of caution is relevant here, however. Quite a few of these studies issue from St. John's University in New York, the location of the Center for the Study of Learning and Teaching Styles; many were conducted by doctoral students affiliated with the university and the Center and remain unpublished (Stahl, 1999).

In another match-mismatch study similar to Virostko's, 99 undergraduate females were categorized as either morning type or evening type. Participants were administered a series of word pairs and were required to decide if the two words were physically identical (word encoding), had the same name (lexical access), or were members of the same semantic category (semantic access). Testing times were 9:00 a.m., 2:00 p.m., and 8:00 p.m. Results showed that the success rate of those classed as morning types decreased throughout the day, while the performance of the evening types improved at later test times. The authors concluded that memory performance is critically dependent on matching time-of-day preference with the time the task is administered (Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991).

As stated previously, some research with preadolescents and early adolescents has suggested that a later peak performance time cannot be assumed for all young people. For example, in an experiment detailed above, time-of-day effects on cognitive processing among 30 Indian children ranging in age from 10-16 years were investigated, with the result that speed and accuracy were found to be significantly higher in the morning than in the afternoon (Rana et al., 1996). Since this research was conducted in India, the findings may reflect cultural differences that result in a circadian pattern that differs from Western societies. If that is the case, then the case for a biological preference for time of day is challenged. Alternatively, the findings may be a reflection of the lower mean age of the sample, when compared to studies using only adolescent participants; the onset of puberty seems to be a precipitating factor in the delayed sleep phase onset hypothesis.

Many researchers (Monk, 1990, and others as noted above) have observed that as people age, they tend to exhibit a greater degree of morningness; that is, they tend to retire and arise earlier than young adults, a phenomenon which usually manifests itself by the age of 50. This may be because peak temperature moves to an earlier time of day as people age (Anderson et al., 1991; Tune, 1969; Webb, 1982). It follows that the optimal time of day for performance in older adults would be during the morning. The impact of matching time of testing and individuals' optimal periods on performing memory tasks between two age groups was examined in two separate studies (May, Hasher, & Stoltzfus, 1993). A pilot study of 210 younger adults, ages 18-22, and 91 older adults, ages 66-78, indicated that most younger participants were evening or neutral types, while most older subjects were morning types. A subsequent study compared memory task scores of 20 younger and 22 older adults tested in either the morning or the late afternoon. Significant age differences were found in the afternoon, with younger subjects obtaining higher scores. However, no differences were found in memory performance of the tasks performed in the morning, a finding that, if recent research is correct, is not surprising.

On a simulated production-line inspection task, the performance efficiency of 10 participants classified either as morning types or evening types was measured. Subjects completed the task for 15 sessions at different times of the day. No significant differences were found for number of items rejected in error. However, correct rejection levels were significantly better in the morning and worse in the evening for morning types than for evening types. Further, the performance improved throughout the day for evening types, while morning types showed a decrease in performance over time. A post-lunch dip in performance was found for morning but not evening types. Interestingly, a significant positive correlation between correct rejections and body temperature was seen for evening types, while a negative correlation was found for morning types (Horne, Brass, & Pettitt, 1980).

Conversely, a study assessing the relationship between morningness-eveningness, time-of-day, and performance on the Multidimensional Aptitude Battery IQ (MAB) and the Inspection Time task (IT) employed 20 male and 50 female participants classified as either morning or evening types. They were administered the MAB and IT tasks in the morning and in the late afternoon. No significant effect for time of testing and morningness-eveningness type was found for most of the tasks. The single exception was the Spatial subtest. Contrary to expectations, morning types performed significantly worse in the morning and better in the afternoon, and evening types performed significantly better in the morning and worse in the afternoon. It was suggested that the reason for this discrepancy is that spatial tasks are performed more successfully when an individual is in a low level of arousal, which is more likely to be the case during a non-optimal time (Song & Stough, 2000).

In a study demonstrating that morningness-eveningness is difficult to detect when all participants are considered, axillary temperature and performance was compared to morningness-eveningness preferences for 19 college students (Almirall, 1993). Participants were identified as morning types, evening types, or neither, according to a morningness-eveningness scale. They were asked to perform three types of tasks, auditory reaction time (to measure alertness and speed), index finger tapping (to measure motor skill), and verbal memory (to assess information processing), during hourly tests in 13 sessions throughout the day. Axillary temperature was taken at each session. No significant differences were found in temperature or performance for morning or evening preference groups. Further, the neither-type individuals did not score with values between the other two groups. Higher axillary temperature was associated with higher performance on the verbal memory and finger tapping tasks, but not the reaction time task.

Thus, it is quite possible that morningness-eveningness preference affects only certain types of tasks. On a simple target-detecting task, morning types detected more targets in the morning, whereas evening types detected more targets in afternoon and evening (Horne et al., 1980). Monk and Leng (1982) were able to specify the type of task performed in accordance with time-of-day preference when they found no interaction between morningness-eveningness and time of day on perceptual-motor tasks, but a significant effect for cognitive tasks.

Some of the strongest evidence supporting the concept of morningness-eveningness as an individual difference, however, comes from a longitudinal study (Cofer et al., 1999). Using research yielding infant sleep data, evidence from chonobiological studies, and evidence from adult light treatment studies, researchers found strong continuity in internal synchronization to light-dark cycles, continuity that varied across individuals and which remained in effect throughout the person's life, at least until he or she was well into adulthood. Environmental influences such as parental modulation during childhood and adolescence, shift work, and other social interaction factors were found to exert some temporary influence on individuals at certain periods of their lives, but, for the most part, a pattern of preference could be detected. The researchers also found that evening types had more difficulty than morning types in adjusting to social and familial demands, since American society strongly favors morning types. The same conclusion was reached on a study of personality aspects involving stress (Mecacci & Rocchetti, 1998). In a study of 232 young adults, aged 20-26, evening types reported more, and more frequent and intense, psychological and psychosomatic problems than morning types. They also showed more problems in coping with social and environmental demands.

A twin study (Hur et al., 1998) offers additional support for Cofer et al.'s work. Genetic influence on chronotype was studied utilizing 205 pairs of monozygotic, reared-together twins (aged 41-47 years), 55 pairs of monozygotic twins reared apart (aged 18-68 years), 50 pairs of dizygotic twins reared apart (aged 22-27 years), and 79 spouses. All completed the MEQ. Genetic variability accounted for 51% of the total variance in the model, with age contributing only 3%. No significance was found between those twins reared together and those reared apart, indicating that the role of the family environment was minimal for this group. The correlation coefficient between spouses was .25, which the researchers interpreted as being the result of "like marrying like," rather than a consequence of marriage itself.

Some individual differences defy categorization. Some, however, deserve mention in connection with specific types of skills. In two studies of relay race teams, individual differences was cited as a possible reason for lack of ability to discern circadian variation in a relay race team. The first study, conducted in 1988 (reported in Krombholz, 1990), examined time-of-day effects on two relay teams participating in the International 24-hour Race in Morlenbach, Germany. In this race, 10-member teams compete for 24 hours, the goal being to achieve the longest distance. Two teams from the same club, participating in 2 successive years, were selected. Team members were 25-54 years of age.

Results showed that performance declined steadily in a linear fashion for both teams from 2:30 p.m. through 2:00 a.m. At that point, Team A continued a linear decline, while Team B seemed to rally; Team B's performance remained steady from 2:00 a.m. to 6:00 a.m., at which time it actually began to increase again, a trend which lasted until 9:00 a.m. Both teams finished, however, at nearly the same point.

In the 1990 study, only Team B's performance proved significant. Team B exhibited the expected outcome: performance which was lowest during the night but which showed a recovery during morning hours and which paralleled the normal body temperature pattern. Krombholz noted that Team A was the poorest trained of all four teams (from both the 1988 and 1990 studies). He postulated that this deficiency in training in addition to sleep deprivation in this 24-hour race made it impossible to detect time-of-day effects in all groups.

Some individual differences he cited include general fitness, experience in competition, and experience on the specific course. He warned, however, that peaks and troughs of performance occurred at different times for even the most prepared runners, and the performance of some poor runners was similar to that of the more experienced. He noted that these individual differences are also found in physiological manifestations of circadian variation, such as body temperature and heart rhythm.

MOTIVATION AS A PRIMARY CONFOUNDING VARIABLE IN TIME-OF-DAY PREFERENCE/ ACADEMIC PERFORMANCE STUDIES

In conducting studies on performance, it must be borne in mind that performance efficiency may depend, either in part or whole, on the motivation of the individual performer (Campbell, 1992). Such a realization places several restrictions on interpretation of data about time-of-day effects. First, a person can perform a given task only while awake; thus, it is impossible to test time-of-day effects during at least one-third of a person's day (Campbell). Even if the person is awakened around the clock to perform tasks, the fact remains that the person is awake during task performance. The nature of the task is important as well; if the participant finds the task interesting and is able to focus on the task, the results may differ significantly from those of a participant who finds no reason to perform at all and certainly not to an optimum level (Campbell).

The confounding motivation effect can be tested in one of several ways. The individual may be tested by changing the time of day while maintaining tasks expected to arouse approximately the same level of motivation; an alternative is to maintain the time of day while varying the motivation. For example, Blake (1971) was able to eliminate diurnal effects on scores on a letter cancellation task by announcing each participant's score to the group of participants. Conversely, time-of-day effects can be introduced by this same manipulation of motivation, which was demonstrated in an experiment in which a vigilance task was given to both control and experimental groups in the early morning and later afternoon (Smith, 1987). Members of the experimental group, however, were told that their results would be made public, thus increasing their anxiety about performing well. The control group showed no difference in its scores, whereas the experimental group exhibited greater anxiety in the afternoon, with an accompanying difference in performance scores: The experimental group performed better in the afternoon.

Therefore, motivation plays many roles in its influence on time-of-day studies. Motivation may vary throughout the day as a function of biological rhythms, manifested as interest, attention, or vigilance. It may also arise from a deeper psychological impetus to do well for reasons entirely outside the testing realm.

OTHER POSSIBLE CONFOUNDING VARIABLES

As stated earlier, some other individual physiological differences play a role in time-of-day variation on performance, including nutrition, amount and quality of sleep, and disease processes or other disorders. It is generally accepted among researchers and lay persons alike that, of these variables, perhaps sleep is the most arbitrary. In fast-paced, achievement-oriented Western society, the ability to forego sleep is sometimes regarded as a strength, a demonstration of character and the ability to suffer for the achievement of a goal. However, for most people, their own experience tells them that when one does not sleep well on a particular night, performance at many tasks on the following day is compromised. The longer the sleep deprivation or poor quality of sleep lasts, the more likely the person is to perceive that his or her performance has diminished.

However, a number of studies reveal that the relationship between quality and quantity of sleep and performance is not by any means a linear one. One very early study (Laird & Wheeler, 1926) showed that participants could be deprived of 2 hours of sleep per night for a week with no change in performance. This very elementary study used only 3 participants, but of the 3, some tasks, such as performing mental multiplication problems, actually improved both in speed and accuracy as time of deprivation increased.

Other research which supports this early evidence includes a 1965 study in which participants were limited to 3 hours of sleep for 8 nights and were asked to perform several types of cognitive tasks, including addition, auditory vigilance, and visual vigilance. Only during the final 2 days of the study were any deficiencies in performance found; even then, participants varied widely both in their own performance and as a group (Webb & Agnew).

In a more recent study (Medeiros, Mendes, Lima, & Araujo, 2001) of 36 medical school students (mean age = 21 years), it was found that 39% of the students had a poor sleep quality, according to the Pittsburgh Sleep Quality Index. This was especially true for those who had tested as evening type on the MEQ. The study concluded that irregularity in the sleep-wake cycle and possible consequent sleep deprivation influence the academic performance of college students. A similar result was obtained by a study of 44 college students under two conditions, 24 hours of sleep deprivation or about 8 hours of sleep (Pilcher & Walters, 1997). The Watson-Glaser Thinking Skills Appraisal was used as a measure of cognition, in addition to a self-report measure of effort, concentration, and performance and another measure of off-task cognition. The sleep-deprived participants performed significantly worse on the Watson-Glaser test, although they rated their concentration, effort, and estimated performance as higher than the nondeprived participants. A reasonable conclusion might be that those who are sleep-deprived may be unable to judge the effects of that deprivation and may not realize the extent to which a lack of sleep may affect their performance. This phenomenon is frequently seen in the college setting in situations in which students choose to postpone preparation for a test or completion of a report until the final hours before they take place or are due and then attempt to produce their best performance under less than ideal conditions.

These two studies are in contrast to another study (Rutala, Witzke, Leko, & Fulginiti, 1990) of 76 fourth-year medical students. Researchers found no significant time-of-day or fatigue-induced effects when student performance on 16 clinical problems presented in 16 separate "stations" was assessed. Analysis of scores included relationships between score and station and score, station, and sequence. In addition, morning station scores were compared against scores for afternoon stations. Finally, a recent study by Siegel (2001), however, found that while sleep is an important prerequisite for acquisition and performance of learned tasks, what remains unproven is that sleep in general, or any particular stage of sleep, plays a major role in memory, a primary component in learning.

TESTING TIME-OF-DAY PREFERENCE

The question to be answered, then, is whether individuals matched to their preferred time of day can be expected to exhibit higher levels of academic achievement than those who are not. It would seem that the answer is obvious: yes. However, the issue is not as simple as that. First, determining one's preferred time of day should probably not be done, as has been the case in many studies, solely by a self-report method, even one which exhibits high reliability and validity coefficients. What must be remembered is that those coefficients demonstrate only that the instrument consistently measures what it is intended to measure. For the MEQ, that means the questionnaire can give a reliable idea of what the participant thinks is his or her preferred time of day, morning, evening, or neither. That does not mean that it can predict a time of best performance, for what people think, especially about themselves, and what can be supported by evidence often differs. Often the testing results in the individual's being placed in the neutral or neither type category. In most of the studies cited in this report, categories of participants were combined. Usually, if the instrument was the MEQ, which it was in the majority of cases, individuals classified as definitely morning type and moderately morning type were combined, as were definitely evening type and moderately evening type. If the goal is to optimize achievement, a quantitative method not reliant on self-report must be used. A combination of two instruments might prove even better.

In an upcoming empirical study, Catholic high school students will be tested to ascertain if matching them to their preferred time of day, as measured by two valid instruments, will result in any significant difference in academic achievement.

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