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ADP013762

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Individual Differences in Vigilance and Performance during Continuous/Sustained Operations

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ABSTRACT

Military operations are often characterised by prolonged periods of wakefulness; irregular rest-activity patterns; long haul flights. These situations are unnatural. Severe sleep debt can accumulate, leading to dangerous levels of sleepiness and decreases of performance. Although sleep deprivation, time of day and time on task are considered among the most important causal factors of daytime sleepiness, the levels of vigilance may still significantly vary according to individual differences. Verifying whether and to what extent some stable individual differences are associated to specific variations of vigilance and performance may be important in orienting the best criteria for the selection of personnel involved in prolonged activity for many hours or unusual hours, and/or monotonous activity.

Concerning individual differences, a distinction can be made between the so-called temporary individual differences and permanent individual differences. The former are to be considered as a series of coping mechanisms, i.e. the set of capacities and abilities that modify workloads or directly affect the homeostatic and/or circadian factors that induce sleepiness. These are considered as the outcome of an active sphere of behaviour which makes individuals directly "involved" in handling their own activities. Permanent differences, instead, are to be considered as "constitutional" differences, i.e. as characteristics that exist for genetic and/or physiological reasons, including gender, age, some personality features (such as extroversion/introversion, field-dependence, etc.) and circadian typology. Some individual coping strategies can minimize the adverse effects of sleep loss and circadian rhythm desynchronization and promote optimal vigilance and performance in operational settings. Equally, some individual traits can facilitate a good adaptability to continuous/sustained operations. Both an age less than 40-50 years and morningness are particularly crucial deteminants of a good adaptability to work at unusual hours and, maybe, to continuous/sustained operations. Equally, both flexibility of sleeping habits and ability to overcome drowsiness are related to both better long-term tolerance in shiftwork and the capacity to sustain vigilance and performance at unusual hours and over time. Studies on other individual traits have given more inconsistent results. Even though it is possible to outline which individual traits are likely to allow better adaptability to continuous/sustained operations, our understanding of the mechanisms involved is still not very clear and definitive. In fact, poor attention has been paid to such important factors as individual ones. There is a surprising lack of studies on individual differences in the adaptability to continuous/sustained operations. Many factors have contributed to this condition. Studies on individual differences are necessarily long, time consuming and require a large sample size. If we can overcome these limitations, then it will be possible to choose the best criteria for the selection of personnel involved in continuous/sustained operations, and also to identify those who run the greater risk of a fall in vigilance and of performance errors in order to adopt the necessary preventive measures.

INTRODUCTION

Military operations are often characterized by prolonged periods of wakefulness, irregular rest-activity patterns and long haul flights. These situations are unnatural. Severe sleep debt can accumulate, leading to dangerous levels of sleepiness, performance decreases and a reduced margin of safety. These factors can increase vulnerability to accidents in operational settings. Although sleep deprivation, time of day and time on task are considered among the most important causal factors of daytime sleepiness (e.g. Åkerstedt and Kecklund, 1994), the levels of vigilance may still significantly vary according to individual differences. Some

Paper produced for the RTO HFM Lecture Series on "Sleep/Wakefulness Management in Continuous/ Sustained Operations", held in Fort Rucker, Alabama, United States, 17-18 June 2002; Warsaw, Poland, 24-25 June 2002; Paris, France, 27-28 June 2002, and published in RTO-EN-016.

individual characteristics contribute, in fact, in modulating general levels and time of day effects of vigilance, sleepiness and performance, and even modulate the intensity with which the various deactivating factors act individually (e.g. Åkerstedt and Torsvall, 1981; Harma, 1993). Verifying whether and to what extent some stable individual differences are associated to specific variations of vigilance and performance may be important in orienting the best criteria for the selection of personnel involved in prolonged activity for many hours or unusual hours, and/or monotonous activity.

The first thing to consider when dealing with the problem of individual differences concerns the distinction made between the so-called *temporary* individual differences and *permanent* individual differences (Harma, 1993). The former are to be considered as a series of coping mechanisms, i.e. the set of capacities and abilities that modify workloads or directly affect the homeostatic and/or circadian factors that induce sleepiness. These are considered as the outcome of an active sphere of behavior, which makes individuals directly "involved" in handling their own activities. Permanent differences, instead, are to be considered as "constitutional" differences, i.e. as characteristics that exist for genetic and/or physiological reasons, including gender, age, some personality features (such as extroversion/introversion, field-dependence, etc.) and circadian typology.

Temporary individual differences or coping mechanisms

Coping strategies for sustaining vigilance and performance during continuous/sustained operations

Coping strategies (or styles) play a major role in an individual's physical and psychological well-being when he or she is confronted with negative or stressful life events (Endler and Parker, 1990). In early research, coping was conceptualized as an unconscious process. In more recent research, however, coping has been considered as a response to external stressful or negative events (e.g. McCrae, 1984). These responses are usually conscious strategies or styles on the part of the individual. Furthermore, some individuals may have particular coping styles in responding to different stressful situations (Carver et al., 1989). Coping behaviours have been categorized into three major coping styles: a) responses that change the situation, b) responses that change the meaning or the appraisal of the stress, and c) responses aimed at controlling distressful feelings (Endler and Parker, 1990). Sustaining vigilance and performance during prolonged periods of wakefulness, continuous operations and/or at unusual hours is a stressful situation; therefore, if people adopt adequate coping strategies, they will be able to reduce the adverse factors affecting continuous/sustained operations and/or shiftwork tolerance.

Coping with the stress of working unusual hours

Commitment to work for many hours or unusual hours may be one of the most important individual factors affecting continuous/sustained operations and/or shiftwork tolerance (Harma, 1993). Depending on the "commitment", several coping mechanisms may be promoting adjustment to work at unusual hours or for a prolonged period. In fact, a good "commitment" allows people to schedule their lives, and especially their sleeping habits (e.g. Monk and Folkard, 1985). For example, people may be able to sleep more before coming to work, take naps during rest periods and adopt adequate eating regimens and physical activity (Rosa, 1990). Good commitment is also affected by financial rewards or by other incentives such as time off and work advancement (Barton 1994; Minors and Waterhouse, 1983).

In short, good "commitment" may be an important factor allowing a good management of vigilance, reducing sleep debt - and therefore sleepiness - during shiftwork and continuous/sustained operations.

Health and physical fitness

Shiftwork and continuous/sustained operations are associated with several acute and chronic health problems, most of which are related to a disarray of circadian rhythms. These health disorders can be greater in people with medical complaints. A less positive attitude to shiftwork has been observed among workers reporting impaired subjective health when compared to those perceiving themselves as relatively healthy (Dirkx, 1987). Negative correlations between attitudes towards shiftwork and the frequency of complaints about chronic fatigue, cardiovascular and psychoneurotic symptoms, and sleep complaints after night shifts have been found. Specifically, it has been suggested that people suffering with digestive tract diseases or sleep disorders should be excluded from job schedules leading to work at unusual hours (Rutenfranz, 1982).

On the other hand, physical fitness is a factor increasing tolerance to working unusual hours (Hanna, 1993). In a series of studies, it was shown that physically-fit subjects reported lower levels of general fatigue and an

increase in sleep length (Harma, 1993). In addition, in one epidemiological study, physical exercise was rated as the most important daily factor promoting sleep and improving its quality (Urponen et al., 1988). Physical fitness thus seems to decrease sleepiness, probably due to improved sleep. In addition, different studies have reported that the rhythm amplitudes of physically-fit subjects are higher than in unfit individuals (Atkinson et al., 1993; Harma et al., 1982). Since individuals with a high amplitude in their circadian rhythms have been found to be more tolerant to shift work, physically-fit subjects should be more tolerant to shiftwork (Reinberg et al., 1988). It is thought that large amplitudes result in a greater stability of circadian rhythms and that this is beneficial in coping with frequent rhythm disturbance (Atkinson et al., 1993).

Flexibility of sleeping habits

Many studies have shown that sleepiness presents a bi-modal distribution with a night-time peak and one in the early hours of the afternoon, defined by Lavie (1986) respectively as "primary and secondary sleep gates". Times of day effects of sleepiness are evident, above all, when the sleep-wake cycle is organized in very short cycles (e.g. 7 min of sleep and 13 of wakefulness). In this case, sleepiness increases during the night showing a trend characterized by two superimposed components: a slow component, which follows a linear circadian trend, and an ultradian quick component. Even vigilance follows a bi-modal distribution that occurs with a strong decrease of sleepiness in a daytime period between 10.00 and 11.00 and in a nighttime period between 21.00 and 23.00, defined by Lavie (1986) as "forbidden zones for sleep". Probably due to high or low levels of rigidity of this circadian and ultradian organization of vigilance, there are subjects who are able to sleep only at specific times. Other individuals seem to have some additional physiological processes, namely "sleep ability" and "wakeability", that allow them to sleep and wake up easily at different times. In other words, the "rigidity-flexibility" in the circadian organization of the sleep-wake cycle might allow a "rigidity-flexibility" of sleeping habits. Based on Folkard and coworkers' (1979) definition, "flexibility of sleeping habits" quantifies the self-reported rigidity in sleeping habits. This individual characteristic should help people to sleep when it is possible and not only when there are the best circadian conditions. Thus, flexibility of sleeping habits should be related to a greater ability to sustain continuous operations and to work at unusual hours, As a matter of the fact, flexibility of sleeping habits is related to better long-term tolerance to shiftwork (e.g. Costa et al., 1989; Iskra-Golek, 1993).

Ability to overcome drowsiness

"Ability to overcome drowsiness" defines the ease with which individuals can overcome drowsiness (Folkard et al., 1979). This factor, too, is related to better long-term tolerance to shiftwork (e.g. Costa et al., 1989; Iskra-Golek, 1993). Furthermore, Vidacek et al. (1987) showed that "ability to overcome drowsiness" was the best indicator of shiftwork tolerance after three years of shiftwork. Like "flexibility of sleeping habits", even this factor seems to be related to characteristics of circadian organization of vigilance, but, unlike the former, it also seems affected by individual coping strategies, In fact, overcoming drowsiness would be facilitated in those subjects who are able to grasp every strategy useful to sustain vigilance and to reduce sleep deprivation. Thus, people with high adaptability to shiftwork and to continuous/sustained operations should be able to: take naps when possible; have appropriate timings of exposure to environmental or bright artificial light; adopt good eating and drinking regimens; do adequate physical exercises.

Napping behavior

Many laboratory studies have documented that napping has positive effects on alertness in various settings (Lumley et al., 1986; Bonnet, 1991; Dinges, 1992; Bonnet et al., 1995; Gillberg et al., 1996; Horne and Reyner, 1996; Reyner and Horne, 1997; Hayashi et al., 1999a, 1999b). In particular, the restorative effects of a short nap (20-30 min) were observed after a normal night's sleep (Hayashi et al., 1999a; 1999b), after a restricted night's sleep (Gillberg et al., 1996; Home and Reyner, 1996; Reyner and Horne, 1997), during 64 hours of continuous work (Naitoh et al., 1992) in young adults, and after a normal night's sleep in the elderly (Ceolim and Menna-Barreto, 2000).

Individual differences in napping behavior allow distinguishing between nappers and non-nappers. Based on an extensive review on napping behavior, Dinges (1992) reported that on average 61% of adults nap at least once a week. Napping more than once within a day is extremely rare. The duration of naps is about 73 minutes; no study found nap duration of <15 min or >120 min to be common.

According to several studies (Evans et al., 1977; Dinges, 1992), naps are taken for the following two reasons: 1) replacement naps, taken in response to a sleep debt, and 2) appetitive naps, taken without regard to sleep

debt, as a result of an endogenous biphasic sleep-wake cycle. In fact, in the regular nappers, there were subjects who reported napping only when tired (subjects defined by Dinges as *replacement or compensatory nappers*); while other subjects reported napping even when not tired, and hence were called *appetitive nappers*. Appetitive nappers appear to be adapted to getting sleep; they not only nap frequently without shortened sleep the night before, but they also report being able to fall asleep almost anywhere, and they do not have to be tired to nap. Since both prophylactic and compensatory napping behaviors are beneficial for reducing sleep loss and for improving performance during continuous/sustained operations, individual differences in napping behavior might be relevant for selecting personnel adapted to sustained prolonged periods of wakefulness.

Coping strategies for improving environmental conditions

Improving the environmental conditions leads to bettering the conditions of workers during continuous/sustained operations. Further, several environmental factors can increase alertness, enhance performance and can partially counter the effects of sleep loss (Penn and Bootzin, 1990). Thus, when environmental conditions are monotonous and not very arousing and when the demands of the task allow it, workers involved in continuous/sustained operations should be able to adopt strategies to improve vigilance, enhance morale and prevent performance decrements over time.

Auditory stimulation: sounds and music as environmental arousers

Meaningful and unpredictable sounds, such as speech, traffic noise and music, generally increase vigilance and improve performance (Davies and Tune, 1969). Noise is not always found to be beneficial, however. Noise produces a decrease in performance if it is loud enough to mask feedback from instruments or inner speech (Poulton, 1977), or if task demands are heavy (Loeb and Alluisi, 1977). Usually, music leads to a higher performance than the one found with noise (Penn and Bootzin, 1990). In addition, music presented on a random schedule increases performance more than continuous music or music presented at a fixed interval (Davies and Parasuraman, 1982). Penn and Bootzin (1990) concluded that background music or other meaningful auditory stimulation played at moderate levels could increase performance, prevent performance decrements over time and enhance morale. Music that is lively and varied is the most arousing,

Bright light

Bright light treatment can be used in managing the physiological mechanisms associated with sleepiness. Exposure to bright light during the night shift can induce physiological adaptation to night shift work and also improve daytime sleep (Czeiler, Jhonson, Duffy, Brown, Ronda, Kronauer, 1990). Exposure to bright light during the night can directly enhance alertness (Badia, Myers, Boecker, Culpepper, 1991) and an increase in vigilance and performance has been found after repeated brief (10 min) green light exposures during the night (Horne, Donlon, Arendt, 1991). Many experimental and some field data suggest that the use of bright light can be very useful for improving alertness and performance during nighttime work and continuous operations.

Ambient temperature

High ambient temperature can be considered as a stressful event. Thus, during continuous/sustained operations and shiftwork it may be appropriate to maintain a constant and moderate temperature (Bonnet, 1990; Lagarde e Batejat, 1995).

Eating and drinking regimen

During continuous/sustained operations workers frequently consume food and drink during breaks. This consumption produces direct effects on arousal. Summing up, light to moderate amounts of high protein foods may help to sustain arousal and high carbohydrate foods may produce sleepiness (e.g. Lennernans, Ambræus e Åkerstedt, 1994; Tepas, 1990). As everybody knows, caffeine has a stimulant effect (e.g. Gillin, 1994). Caffeine is found not only in coffee but also in tea, chocolate, and Coca-Cola. Caffeine may be used effectively as a stimulant to combat sleepiness. Individuals differ in their response to caffeine, with some people being overstimulated. Others are less affected, especially chronic users who appear to develop some tolerance to the stimulating effect of caffeine. Further, an indiscriminate use of caffeine may lead to deleterious effects on sleep (Gillin, 1994). Daytime ingestion of alcohol may promote sleepiness and a small amount of alcohol it often used to induce sleep propensity. Although low-to-moderate amounts of alcohol initially promote sleep by shortening sleep latency and reducing wakefulness for 3 to 4 hours of the night, it often disrupts and fragments sleep during the latter half of the night (Gillin, 1994).

Sleep hygiene

Many deleterious effects of continuous/sustained operations are the result of sleep deprivation. Thus, proper information on factors that affect sleep is very important in order to adopt adequate coping strategies. Sleep hygiene includes information on the effects of sleep loss, sleep scheduling, circadian rhythms, naps, sleep habits, caffeine, cigarette smoking, alcohol, ambient temperature, environmental light and environmental noise on sleep (Penn and Bootzin, 1990). Zarcone (1,994) proposed some rules for obtaining good sleep, which are adapted for people with regular night sleep opportunity. It should also be useful to propose general rules in order to facilitate proper sleep in workers involved in continuous/sustained operations.

Permanent or constitutional individual differences

Circadian rhythm desynchronization

Most behavioral and physiological processes are characterized by a temporal structure that matches the 24-h day-night cycle. The most salient behavioral marker circadian rhythmic output in human adults is the daily sleep-wake cycle. A similar 24-h time frame constrains a myriad of functions, including endocrine secretions, body temperature regulation, gastrointestinal functions, sensory processing and cognitive performance (e.g. Moore-Ede et al., 1982). Many of these rhythms are usually synchronized. Prolonged periods of wakefulness, irregular rest-activity patterns, and working for many hours and/or at unusual hours, leads to a transient and repeated misalignment of circadian rhythms. During the circadian realignment process there are three mechanisms by which mood, well-being and performance efficiency can be adversely affected. First, sleep will be disrupted and the individual will be in a state of partial sleep deprivation. Second, the new time of wakefulness is likely to tap into the "down phases" of various psychological functions that are normally coincident with sleep in the day-oriented individual. Third, the various individual components of the circadian system will be in a state of disarray, with the normal harmony of appropriate phase relationships destroyed (e.g. Åkerstedt et al., 1989). Following on from this, working at unusual hours can cause sleepiness, gastrointestinal symptoms and a decrease in performance. Circadian adjustment is slow. In addition, fast circadian adjustment may be beneficial only in slowly rotating shift systems, while in rapidly rotating shift schedules, fast circadian adjustment may be unnecessary and even detrimental. Depending on the coping strategies adopted – and also perhaps on some physiological traits – strong individual differences in the amount of circadian rhythm desynchronization can be evident. As a matter of fact, desynchronization of circadian rhythms of body temperature and sleep-wakefulness has been found in a majority of subjects with poor tolerance to shiftwork (e.g. Reinberg et al., 1989).

"Sleepy" and "Alert" subjects

Studies using very short sleep-wake cycles (e.g. 7 min of sleep and 13 of wakefulness) (Lavie, 1992) or subjective measures of sleepiness, as *Epworth Sleepiness Scale* (Johns, 1991a) allow distinguishing between "sleepy" and "alert" subjects.

The *Epworth Sleepiness Scale* (ESS) (Johns, 1991 a) is a brief self-administered questionnaire which asks subject to rate, on a scale of 0-3, the chances that in recent times he/she would have dozed in eight specific situations of daily life, that are more or less soporific. The subject is required to retrospectively evaluate part of his/her usual behaviour and to distinguish dozing behaviour from feelings of tiredness. This very simple method for evaluating daytime sleepiness seems to reflect a steady individual trait; in fact, test retest administrations show that paired ESS scores do not change significantly and are highly correlated (Johns, 1991b). In patients suffering from sleep disorders, ESS scores are correlated with mean sleep onset latencies measured in a *Multiple Sleep Latency Test* (MSLT). Finally, the ESS scores significantly distinguish normal subjects from several groups of patients with sleep disorders characterised by different levels of daytime sleepiness (Johns, 1991b). A study considering two groups of college students with low (alert subjects) and high (sleepy subjects) ESS scores showed that sleepy subjects, as compared to alert subjects, evaluated themselves as more sleepy, had more episodes of daytime sleepiness, presented a greater number of naps and their naps had a longer duration (Casagrande, Violani, Testa, Curcio, 1997). In addition, sleepy subjects had the worst performance on a Letter Cancellation Task with respect to alert subjects (Casagrande, Violani, Curcio, Bertini M, 1997)

The reliability and validity of the ESS, the rapid completion time, test length and ease of self-administration make it a useful measure for evaluating daytime sleepiness as a persistent individual trait. Sleepy subjects complain of high levels of daytime sleepiness, can easily fall asleep when instructed to do so, but also fall

asleep when instructed to remain awake; finally, they need a greater amount of sleep. Alert subjects, on the other hand, do not complain of daytime sleepiness, cannot easily fall asleep when instructed to do so, but can easily remain awake; finally, compared to sleepy subjects, they need less sleep (Lavie, 1992). Due to these individual differences along the sleepy-alert continuum, alert subjects seem to be more suitable for sustaining continuous operations.

Morning types and evening types

Kleitman (1963) was the first investigator to propose the existence of morning and evening type subjects, whose body temperature and efficiency curves peaked at different times during the sleep-wake cycle. Individual differences in chronotypology have been investigated by means of questionnaires. Oquist (1970) formulated a questionnaire in order to classify subjects on the basis of their self-assessed preference for time of day. He described Morning-types (M-types), Intermediate or Neither types (N-types) and Evening types (E-types). Horne and Hostberg (1976) produced a new version of this questionnaire: the Morningness-Eveningness Questionnaire (MEQ). It consists of 19 questions on individual rising and bedtimes, preferred times for physical and mental activity, and subjective alertness. The questionnaire has been standardized in various countries. The use of the MEQ in research into biological rhythm has provided significant results. There is general agreement that morning persons reach their peak body temperature and diurnal efficiency, 2-3 hrs earlier than evening persons (e.g. Horne et al., 1980; Foret et al., 1982). With regard to sleep habits, M-types have earlier bed times and rising times than E-types (e.g. Froberg, 1977; Kerkhof, 1985). With respect to the sleep-wake cycle, M and E-types differ in phase position, regularity and flexibility, and E-types have a more flexible sleep-wake cycle than morning type persons (e.g., Foret et al., 1982; Kerkhof, 1985; Ishihara et al., 1987).

Vidacek et al (1988) found a phase-advance difference of nearly four hours in morning types. Ishihara et al (1987) found that, except for REM latency, which was shorter in morning types, there were no differences in the polysomnographically recorded sleep parameters; but, other authors (Foret et al., 1985; Kerkhof, 1991) failed to replicate this finding. Lavie and Segal (1989) evaluated differences in the structure of daytime sleepiness. Nocturnal sleep efficiency was higher in morning than in evening types. After sleep deprivation, evening types slept more during the morning period, whereas a mid-afternoon peak in sleepiness was not found in this group. Evening types were sleepier during the morning but, on the whole, suffered less from daytime sleepiness and had a better performance on a Letter Cancellation Task with respect to morning type subjects (Casagrande, Violani, Curcio, Bertini, 1997). On the other hand, Froberg (1977) found no significant differences between M and E-types in letter cancelling, maze learning, syllogism and numerical vigilance, measured 3-hourly during 75 h of sleep deprivation. Åkerstedt and Froberg (1976) reported no M-E type differences in an auditory addition and attention test given five times over one day. Patkai (1971) measured performance with the Stroop test, arithmetic ability and reaction time at three times over a day. Significant M-E type differences were found only for the latter task. Horne et al (1980) reported significant differences between M and E-types in the number of items correctly rejected in a line inspection task. M-types' correct rejection levels were significantly better than E-types' in the morning, whereas they were worse during the evening. Whilst E-types showed a steady improvement throughout the day, M-types showed a general decline. A post-lunch dip in performance was quite evident for M-types, but not for E-types. In addition, the circadian trends in correct rejection levels and body temperature were highly positively correlated for E-types, but a significant negative relationship between these parameters was found for M-types.

In a review of findings on morningness and eveningness, Kerkhof (1985) concluded that morning types exhibited a relatively advanced phase position of their sleep-wake behavior, subjective alertness and body temperature when compared to evening types. In addition, on the basis of the less intraindividual variability of sleep times, the smaller numbers of nocturnal awakenings, the higher sleep quality and the lower frequency of naps during morning hours, Volk et al (1994) suggested a stronger synchronization of the sleep-wake cycle in morning types.

The difference in circadian phase position between M and E types is believed to influence their different adaptability and tolerance to night-work, with M-types being less tolerant (e.g. Breithaupt et al., 1978). Conversely, Costa et al (1989) found that morningness appeared to be unrelated to long term tolerance, but did influence circadian adjustment and sleep behavior. M-types showed less delay in their circadian phase-position and less of an adjustment in their sleeping times. In addition, Costa et al. (1989) found that subjects with digestive disorders showed a greater phase shift and a reduction in amplitude on night work, suggesting a possible relationship also between short-term circadian adjustment and long-term tolerance to shiftwork.

Some studies attempt to relate individual differences in Morningness with Eysenck's personality dimensions. There are studies which find a correlation between morningness and extraversion but not between morningness and neuroticism: M-types tending to be more introverted than E-types (e.g., Folkard et al., 1979; Ishihara et al., 1987; Wilson, 1990).

Introversion and extroversion

According to Eysenck's (1967) theory, large numbers of empirical investigations find three major dimensions of personality: extraversion-introversion (E-I), neuroticism-stability, and psychoticism-superego. These three dimensions appear to be relatively immune to cultural factors and have a strong genetic basis, which suggests that there must be some psychological, anatomical or biochemical-hormonal factors underlying the observed behavior patterns. Eysenck's first explanation of E-I was in terms of excitation-inhibition balance. In extraverts, hypothetical inhibitory potentials would develop rapidly and dissipate slowly. Later, the theory of E-I was reformulated in terms of the arousal concept. Individual differences in E-I would be associated with states of arousal in the cortex, mediated probably by the reticular formation. Compared to extraverts, introverts are hypothesized to be more cortically aroused. In addition, there is thought to be an inverted U arousal-performance relationship. In monotonous situations, introverts would sustain their attention better than extraverts, but factors changing levels of arousal (noise, time of day and so on) could reverse performance trends. Eysenck has also suggested a link between vigilance and arousal. Arousal facilitates the maintenance of attention over time; hence, introverts do better than extraverts. Several extensions of Eysenck's theory have been introduced. Humphreys and Revelle (1984) explained task performance in terms of both arousal, considered as resource availability, and effort, considered as resource allocation. Hockey (1986) proposed that introverts have more internal control over their activity than extraverts, with the consequence that the performance of introverts is affected much less than that of extraverts by manipulation of arousers (such as noise, incentives and so on). M.W. Eysenck (1988) suggested that introverts differ from extraverts in arousability rather than in basal levels of arousal.

On the other side of the physiological characteristics of the I-E dimension, what is the relationship between the E-I dimension, on the one hand, and vigilance and performance, on the other? There are contrasting experimental results with regard to this issue. Blake and Corcoran (1972) found that introverted subjects had better performance than extroverts in the morning, whilst they showed a steady decrease in performance throughout the day. Some studies reported a possible relationship between the I-E dimension and tolerance to shiftwork (Blake and Corcoran, 1972; Colquhoun and Folkard, 1978; Iskra-Golek, 1993). Extroverted subjects should be more tolerant to shiftwork than introverts, whereas introverts had better performance and suffered less frequently from drowsiness. After considering 56 experiments on the relationship between E-I and vigilance/performance, Koelega (1992) found that 40 (70%) of them fail to show a difference in favour of introverts in the overall performance level. The main finding of a meta-analysis showed that: many studies have failed to support E-I differences in vigilance tasks; more E-I differences are found in visual tasks than in auditory tasks and in studies using extreme introverts and extraverts; when extreme introverts and extraverts are considered, introverts are superior in absolute levels of detection but not in maintaining detection efficiency over time (Koelega, 1992).

Neuroticism

Neuroticism-stability is one of the dimensions of Eysenck's (1967) theory. According to Eysenck's (1967) theory, individual differences in neuroticism are associated with the limbic system and differences in psychoticism are associated with androgen hormones.

Subjects with higher scores on neuroticism had a faster performance on a visual search task and evaluated themselves as more tired (Casagrande, Violani, Curcio, Bertini, 1997). Colquhoun and Folkard (1978) found that "neurotic-extrovert" subjects show the greatest degree of adjustment of their body temperature rhythms to phase shifts; while Nachreiner (1975) pointed out that more introverted and emotionally unstable subjects are less tolerant to shiftwork.

Field dependence

Some studies (Sarmany, 1984) attempted to relate vigilance and sleep with individual differences in cognitive style, such as those hypothesized by the field-dependence personality theory. Witkin and co-workers (Witkin, Dyk, Faterson, Goodenough and Karp, 1962) proposed that individuals differ along the field dependence-independence continuum. According to the field-dependence theory, characteristics of field-independent

individuals include: a) a high degree of analytical ability, that is, the capacity to separate the relevant from the irrelevant (vs. a more global style); b) an active and objective approach (vs. a passive and subjective approach); c) a relatively greater control of impulses and mood (vs. greater impulsivity); d) less manifest anxiety; e) a more well-defined sense of identity, as well as more self-confidence. In addition, field-dependent individuals should be more arousers and thus they should be less sleepy than field-independent subjects. There are contrasting experimental results on this issue. Some studies found that field-dependent individuals have higher levels of vigilance and a better performance (Natale, 1997; Rhodewalt and O'Keeffe, 1986), whereas others found that field-dependent subjects as compared to field-independent subjects were less sleepy only in the morning (Casagrande, Violani, Curcio, Bertini, 1997), and had a worst performance (Casagrande, Violani, Curcio, Bertini, 1997; Marincola and Long, 1985).

Age

Age is one of the major predictors of sleep length and sleep quality in connection to the night shift. It is suggested that proneness to internal desynchronization of the circadian system increases with age, making it more susceptible to a disturbance of the sleep-wake pattern (Åkerstedt and Torsvall, 1981). It appears that at around 45 years of age, difficulties in connection with the night shift start to increase with increased exposure to the night shift. The reason for the negative effects of experience are unclear, but one might think that decreased circadian flexibility could be involved and that more time for recuperation with increasing age causes an accumulation of negative effects (Åkerstedt and Torsvall, 1981; Foret et al., 1982). In addition, there is evidence to suggest that people become more M-type as they get older. Thus, morningness might also play a role in explaining some of the problems that the late middle-aged and elderly have in coping with shiftwork (Monk, 1990).

Gender

In a study investigating the differences between male and female shiftworkers, Oginska et al. (1993) found that men slept more than women and that women experienced more sleep disturbances than men and suffered more frequently from drowsiness during work. It would be difficult to judge whether an insufficient amount of sleep in case of shiftworking women and their drowsiness at work should be considered as relating to a biological-based greater need for sleep; it might rather be the result of the double burden of female workers: the job and family. However, studies comparing male and female workers with a similar workload have not found differences between genders in shiftwork tolerance (e.g. Olsson et al., 1990). Women generally suffered more than men from symptoms considered as specific to the "intolerance syndrome", i.e. psychoneurotic, digestive and circulatory symptoms, and those of chronic fatigue. However, after 40-50 years their subjective health generally improved, whereas in males one observed the consequent deterioration of health with advancing age.

CONCLUSIONS

In industrialized societies, there are an increasing number of situations (i.e. continuous work in essential services and in high responsibility tasks) that require sustained operations during which irregular rest-activity patterns are needed. The attempt to sleep and to work at unusual hours (to sleep during the day and to work during the night), with respect to the underlying circadian rhythm, often causes loss and/or changes in the structure of sleep and increased sleepiness. If, as normally happens during intense military operations, it becomes necessary to prolong irregular rest-activity patterns for some days in stressful situations, a severe sleep debt and circadian rhythm disruption can accumulate. Both of these physiological factors lead to increased sleepiness, decreased performance and reduced margin of safety on the job. All of these factors increase vulnerability to accidents and mistakes in operational settings.

Alertness management strategies can minimize the adverse effects of sleep loss and circadian rhythm desynchronization and promote optimal vigilance and performance in operational settings. No single strategy can fully counteract the sleepiness and performance decrements typically recorded during night shifts and continuous operations. A combination of strategies may provide the greatest potential to optimize alertness and performance in operational settings. To improve performance and to effectively contrast the adverse interactions of the aforementioned factors, one possibility is to use short periods of "prophylactic sleep" (before long periods of work) or to take naps during the work period (Nicholson 1986). Other useful strategies could be: multiple napping regimens; bright light treatment; adopting behaviors encouraging health and

physical fitness; promoting coping strategies to improve both flexibility of sleeping habits and the ability to overcome drowsiness; training people to adapt coping strategies for improving environmental conditions. The levels of vigilance may also significantly vary according to individual differences. Some individual traits contribute, in fact, in modulating general levels and time of day effects of vigilance.

According to studies on interindividual differences, it might be concluded that there are some people who suffer very little from working at unusual hours or for prolonged periods, while others find it almost intolerable. A number of authors have shown that age and morningness-eveningness are particularly crucial determinants of a good adaptability to work at unusual hours and, maybe, to continuous/sustained operations. Some authors have shown that extreme M-types suffer more from shiftwork and prolonged periods of wakefulness than E-types subjects. The reason for this difference may include the reduced susceptibility to physical zeitgebers shown by E-types and the difficulties that morning types have in sleeping late during the morning. Although individual traits should remain constant throughout life, there is evidence to suggest that people become more "M-type" as they get older. Thus, morningness might also play a role in explaining some of the problems that the late middle-aged and elderly have in coping with working at unusual hours (Monk, 1990). Equally, both flexibility of sleeping habits and the ability to overcome drowsiness are related to both better long-term tolerance in shiftwork and the capacity to sustain vigilance and performance at unusual hours and over time. Studies on other individual traits have given more inconsistent results. Although some approaches appear very productive, much more work needs to be done in order to have accurate reliable results on this topic.

Even though it is possible to outline which individual traits are likely to allow better adaptability to continuous/sustained operations, our understanding of the mechanisms involved is still not very clear and definitive. In fact, poor attention has been paid to such important factors as individual ones. Most studies on individual differences have considered vigilance and performance during night shifts or have focused on shiftwork tolerance. Very few studies have considered individual differences in the management of sleep loss or have considered sleep deprivation tolerance. Furthermore, there is a surprising lack of studies on individual differences in the adaptability to continuous/sustained operations. Many factors have contributed to this condition. Studies on individual differences are necessarily long, time consuming and require a large sample size.

To find out which individual characteristics can guarantee the best adaptability to sustained operations and to irregular or unusual rest-activity schedules, it is essential to define: a) which physiological, behavioral and/or psychological parameters are useful for defining the "adaptability dimension"; b) which individual traits can allow us to predict adequate adaptability. To evaluate both the "adaptability construct" and "individual traits", it is necessary to take into account a very large number of variables: psychological, subjective, behavioral, physiological/biological, psychophysiological, and chronobiological. It is also necessary to use a multivariate statistical approach, which necessarily calls for very large samples of subjects (it is estimated that about 12 observations are needed for each considered variable). If we can overcome these limitations, then it will be possible to choose the best criteria for the selection of personnel involved in continuous/sustained operations, and also to identify those who run the greater risk of a fall in vigilance and of performance errors in order to adopt the necessary preventive measures.

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