AGE AND INDIVIDUAL SLEEP CHARACTERISTICS AFFECT COGNITIVE PERFORMANCE IN ANESTHESIOLOGY RESIDENTS AFTER A 24-HOUR SHIFT

Meri Tadinac[1], Ante Sekulić[2], Ivana Hromatko[1], Branka Mazul-Sunko[3] and Romina Ivančić[4]

[1]Department of Psychology, Faculty of Humanities and Social Sciences, University of Zagreb; [2]Division of Neuroanesthesia and Neurointensive Care, University Department of Anesthesiology, Zagreb University Hospital Center; [3]University Department of Anesthesiology and Intensive Care, Sveti Duh University Hospital; [4]VIPnet d.o.o., Zagreb, Croatia

SUMMARY – Previous research has shown that both shift work and sleep deprivation have an adverse influence on various aspects of human cognitive performance. The aim of this study was to explore changes in cognitive functioning and subjective sleepiness of anesthesiology residents after a 24-hour shift. Twenty-six anesthesiology residents completed a set of psychological instruments at the beginning and at the end of the shift, as well as a questionnaire regarding information about the shift, Stanford Sleepiness Scale, and Circadian Type Questionnaire. There was a significant decline in cognitive performance measured by the Auditory Verbal Learning Test after the shift. The effect was stronger in older participants and in those with high scores on rigidity of sleep scale and low scores on the ability to overcome sleepiness scale. There were no differences in the digits forward test (a measure of concentration), while digits backward test (a measure of working memory) even showed an improved performance after the shift. Although participants reported being significantly sleepier after the shift, the subjective sleepiness did not correlate with any of the objective measures of cognitive performance. In conclusion, the performance in short tasks involving concentration and working memory was not impaired, while performance in long-term and monotone tasks declined after sleep deprivation, and the magnitude of this decline depended on the specific individual characteristics of sleep and on age. Surprisingly, age seemed to have an important impact on cognitive functions after shift work even in the relatively age-homogeneous population of young anesthesiology residents.

Key words: *Work schedule tolerance; Internship and residency; Anesthesiology; Cognition; Memory; Verbal learning; Sleep deprivation; Stress, psychological; Burnout, professional*

Introduction

Sleep disruption, like the one experienced by long-term rotating shift workers, is a physiological stressor that causes a variety of adverse physical, psychological and cognitive symptoms. It has been shown that shift work has an adverse influence on human health[1], mood[2] and cognitive functions[3,4]. A similar pattern of results has been found in sleep deprivation studies[5,6]. For example, following 24-hour sleep deprivation, subjects showed psychomotor function equivalent to those with a 1‰ blood alcohol concentration[7]. Chronic sleep deprivation, even a partial one (defined as 6 or less hours of sleep a day during a period of at least two weeks) is equivalent to two nights of complete sleep deprivation[8] and results in diminished cognitive performance. Medical staff, particularly trainees, work

Correspondence to: *Prof. Meri Tadinac*, Department of Psychology, Faculty of Humanities and Social Sciences, University of Zagreb, Ivana Lučića 3, HR-10000 Zagreb, Croatia
E-mail: mtadinac@ffzg.hr

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long hours and are often sleep deprived[9]. Most health care providers are also required to take care of patients in various times of day and night, i.e. to work long and variable hours. Shift work, by definition, involves altered sleep/wake patterns. Therefore, the physicians' work is often subject to the adverse effects of both shift work and sleep deprivation.

Sleep deprivation of the magnitude experienced by medical trainees has been shown to impair performance, worsen mood, and compromise patient and provider safety[10,11]. After a night on call, physicians have reduced retention capacity[3], short-term memory[12], concentration[13], and speed and mental endurance[14]. In different work settings, it has been shown that shifts lasting longer than 8 hours lead to more worker fatigue and higher risk of accidents[15]. And yet, medical personnel, even older physicians, often work 24- to 30-hour shifts[16].

Circadian rhythms are governed by an internal oscillator that is resistant to change[17], which makes adjustment to their disruption difficult. Homeostatic and circadian processes interact to determine waking neurobehavioral alertness as expressed in fatigue and performance[18]. Although the notion of importance of endogenous factors in adjustment to night work is not a new one[19], there is a relatively recent rise of interest in the study of individual differences in tolerance of sleep loss[20,21]. Inter-individual differences in circadian amplitude, circadian phase, and mean performance level are widely reported, and the recognition of these biologic differences has been accompanied with the development of self-report measures that indirectly assess biologic parameters considered sensitive to shift work adjustment. Among such measures are the Morningness-Eveningness Questionnaire, which measures the tendency to be an early 'lark' or a late 'owl'[22], and the Circadian Type Questionnaire, which measures two dimensions – the ability to overcome sleepiness and the rigidity of sleeping habits[23].

Some studies have suggested that anesthesiologist's performance, especially in tasks demanding vigilance such as monitoring the patient, might be particularly vulnerable to the effects of fatigue[24]. Therefore, the aim of this study was to compare the performance on several cognitive tasks in a group of anesthesiology residents before and after 24-hour shift, as well as to determine whether the performance after sleep deprivation is related to the individual characteristics of sleep.

Subjects and Methods

Twenty-six healthy young (6 of them males, age range 26-35, mean age = 29.9 years), anesthesiology residents at two university hospitals in Zagreb, participated in the study. They completed a set of psychological instruments at the beginning of the shift (around 8:00 AM), and then again the parallel forms of the same set of instruments at the end of the shift (around 8:00 AM on the next day). The Circadian Type Questionnaire was administered in the pre-shift testing only, as it measures stable individual characteristics of sleep. During the post-shift trial, the participants also completed a questionnaire providing information on the shift (how stressful it was, whether they had a chance to sleep and for how long).

Instruments

Digit span

Digit span tests how many bits of information a person can attend to at once and repeat in order. It comprises two different tests, digits forward and digits backward, which involve different mental activities[25]. Both tests consist of random number sequences which appear on the screen at the rate of one *per* second. In digits forward test, the subject's task is to repeat each sequence exactly as it is given. In this study, we used a PC screen presentation of number sequences, in order to avoid variations in testing procedure, which can happen when the experimenter reads the numbers aloud (e.g., spontaneous creation of chunks while reading the numbers, which results in a longer sequence of remembered numbers than would be the case otherwise). When the sequence is repeated correctly, the program generates the next, longer number sequence (the starting sequence is three digit long), continuing until the subject fails the same-length sequence twice in a roll. This subtest measures the efficiency of attention (a passive span of apprehension). In digits backward subtest, the starting sequence is two digit long. The subject's task is to repeat the digits in exact reversed order from the one in which they had appeared on the screen. Again, the test continues until the subject fails to repeat the same-length sequence twice in a roll. This test requires not only storage, but an additional mental operation of reversing the sequence, thus measuring working memory (internal visual scanning is required in order to efficiently solve the task).

Auditory Verbal Learning Test

The Auditory Verbal Learning Test[26] measures immediate memory span, provides a learning curve, and elicits retroactive and proactive interference tendencies. The Croatian version of this classic verbal memory test was administered, as described by Lezak[25]. The test consists of 15 unrelated common nouns that are read to the subject on five consecutive trials. Each trial is followed by a free recall test. Then another list is being introduced (list B, with a new set of words), followed by sixth trial of the A list (proactive and retroactive interference trials). Total recall after each learning trial, and an interference measure (difference in the number of recalled words between sixth and fifth trial) were selected as the key variables for this test.

Circadian Type Inventory

The Circadian Type Inventory[23] consists of 19 items. The questionnaire contains two subscales, vigorousness (languid/vigorous) and flexibility (flexibility/rigidity of sleeping habits). Rigid types report that they are less able to sleep in unusual hours; they have a preference to sleep and eat at regular times. Languid types find it difficult to overcome drowsiness and feel lethargic following reduced sleep. A high score describes individuals who prefer working at normal times of day and find it easy to wake in the morning. In general, the authors report that vigorous and flexible types showed better circadian adjustment on a number of psychological and physiological measures.

The Stanford Sleepiness Scale

A seven point Likert-type scale (Stanford Sleepiness Scale[27]) has descriptors ranging from 'very alert' to 'very sleepy'. The subject is instructed to choose the set of descriptors that best describe his/her feeling of sleepiness at the given moment.

Results

Cognitive performance and subjective sleepiness before and after the shift

Auditory Verbal Learning Test

Multivariate repeated measures ANOVA with time of testing (before and after the shift) as an independent variable and total number of recalled words *per* trial as dependent variables showed a significant main effect of the time of testing ($F=3.19$, $p<0.002$). Results for separate trials are shown in Table 1. The total number of recalled words is shown in Figure 1.

The magnitude of the interference (difference between the total number of words recalled on 5th trial and total number of words recalled on 6th trial) corre-

Table 1. Results of multivariate repeated measures ANOVA with time of testing (before and after the shift) as an independent variable, and total number of recalled words per *trial as dependent variables*

Trial	Sum of squares	df	Mean square	F	p
1	14.019		14.019	7.382	0.012
2	26.327		26.327	8.640	0.007
3	33.923		33.923	15.123	0.001
4	12.019	1/25	12.019	6.328	0.019
5	17.308		17.308	17.523	0.001
B list	9.308		9.308	8.403	0.008
6	19.692		19.692	5.333	0.029

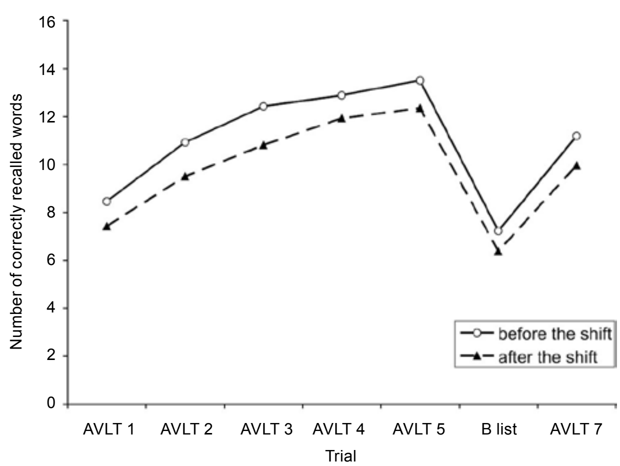

Fig. 1. Number of correctly recalled words in a standard audiovisual learning memory test.

lated positively with the age of subjects only after the shift ($r=0.41$, $p<0.05$), but not before the shift ($r=0.28$, ns).

Digit span

Multivariate repeated measures ANOVA with the time of testing (before and after the shift) as an independent variable, and total number of recalled numbers forward and backward as dependent variables showed a significant main effect of the time of testing ($F=3.19$, $p<0.002$). The total number of recalled numbers is shown in Figure 2. As seen from Figure 2, the ability to concentrate did not change after the shift ($F=0.14$, ns), while the working memory scores were increased ($F=4.74$, $p<0.04$).

Subjective sleepiness

As expected, the residents felt significantly sleepier after the shift ($M=2.3$, $SD=0.88$) than before the shift ($M=3.2$, $SD=1.02$; $F=13.3$, $p<.001$). However, this subjective measure of sleepiness did not correlate with any of the objective measures of cognitive functioning ($r_{AVLT} = -0.06$; $r_{attention}= -0.37$; $r_{working\ memory}= -0.37$; ns all).

Cognitive performance in relation to sleep characteristics

Auditory Verbal Learning Test

As expected, neither vigorousness nor flexibility scale correlated with the Auditory Verbal Learning Test score before the shift ($r_{rs}=0.04$; $r_v=-0.31$, ns). However, the score on the rigidity scale was significantly negatively correlated with the Auditory Verbal Learning Test score after the shift ($r=-0.50$, $p<0.01$), suggesting diminished retention capacities in rigid sleepers after the shift-induced sleep loss. A similar effect was expected for the vigorousness scale, but this correlation did not reach statistical significance ($r=0.22$, ns).

Furthermore, the higher the score on rigidity scale, the greater was decline in the total number of recalled words after the shift ($r=0.37$, $p<0.05$), and similarly, the higher the score on vigorousness scale, the lesser was decline in the total number of recalled words after the shift ($r=-0.44$, $p<0.03$).

Digit span

The pattern of results for digits forward test was similar to the one obtained with Auditory Verbal Learning Test, i.e. neither rigidity nor vigorousness scale correlated with the efficiency of attention scores before the shift ($r_{rs}=-0.31$; $r_v=0.11$, ns), while after the shift those with higher scores on rigidity dimension had lower scores on the efficiency of attention test ($r_{rs}=-0.41$, $p<0.05$). Although a relation between vigorousness and attention could be expected as well, it did not reach statistical significance ($r_v=0.17$, ns).

Performance on the digits span backward test (a working memory measure) did not correlate with characteristics of sleep scales either before ($r_{rs}=-0.18$; $r_v=-0.09$, ns) or after the shift ($r_{rs}=-0.23$, $r_v=0.18$, ns).

Furthermore, we examined the relationship between the flexible-rigid and languid-vigorous dimensions and the actual amount of sleep residents reported having during the shift; rigid sleepers were able to take fewer naps during the shift than flexible sleepers ($r=-0.46$, $p<0.02$), while vigorousness was not correlated with the amount of sleep ($r=-0.02$, ns). This can also explain the absence of correlation between vigorousness scale and any of the cognitive measures used in the study.

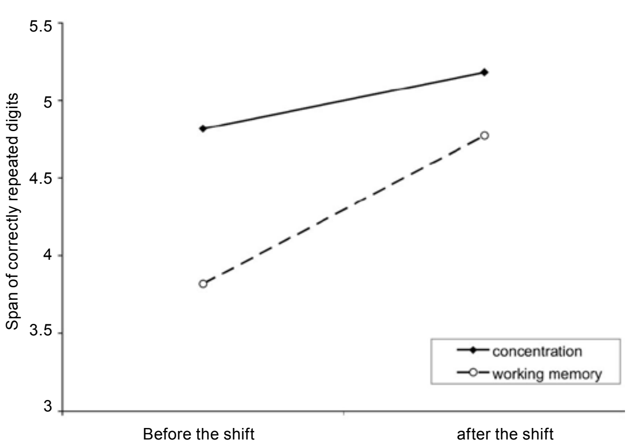

Fig. 2. Span of correctly repeated digits forward (concentration) and backward (working memory).

Discussion

Multivariate repeated measures ANOVA with the time of testing (before and after the shift) as an independent variable and total number of recalled words *per* trial as dependent variables showed a significant main effect of the time of testing. As shown in Figure 1, both learning curves showed a normal pattern (steady rise in the number of learned words with each trial and a small decline after the inserted B list), but the test taken before the shift has a higher curve, i.e. a higher number of remembered words on each trial, compared with the test taken after the shift, suggesting that even one night of lost sleep reduced the retention capacities.

Interestingly enough, although the age range of our subjects was relatively narrow (26-35 years), the magnitude of the interference after the shift correlated positively with age, suggesting that sleep loss caused greater damage to the retention capacities in older subjects. It is likely that this correlation would be even higher if the age span was wider, as the magnitude of the interference would be larger in older subjects[28]. As there was no correlation between age and interference magnitude in the pre-shift trial, it is concluded that the sleep loss *per se*, and not just the age of the participant accounted for the larger interference. This is in accordance with some previous findings that 24 hours on call are particularly stressful for older anesthesiologists[16].

Regarding the individual characteristics of sleep, we did not expect a correlation between the scales of sleep rigidity and vigorousness with any of the cognitive measures before the shift. However, we did expect those dimensions to influence the performance after the sleep loss, and indeed, the score on the rigidity of sleep scale correlated significantly negatively with the Auditory Verbal Learning Test score after the shift, suggesting diminished retention capacities in rigid sleepers after the shift-induced sleep loss. Although a similar effect was also expected for the vigorousness scale, this correlation did not reach statistical significance.

Furthermore, the higher the score on the rigidity of sleep scale, the greater was decline in the total number of recalled words after the shift. Vigorousness scale also proved to be predictive for this result, i.e. the higher the score on the vigorousness scale, the lesser was decline in the total number of recalled words after the shift. Some recent research resulted in a proposal of a trait-like differential vulnerability to sleep loss, since the behavioral impairment caused by sleep loss was significantly different among individuals, stable within individuals, and robust relative to experimental manipulation of sleep history[20,29]. Our results suggest that differential vulnerability to sleep loss could be partly based on sleep rigidity and vigorousness. These findings might have even further repercussions, as it has been demonstrated in longitudinal studies[30,31], showing that the rigidity/flexibility and languidness/vigorousness constructs are important predictors of long-term health outcomes. The authors of these studies administered a battery of measures to a workforce about to enter rotating shift work; at both one-year and 3-year follow up, the Circadian Type Questionnaire was the best predictor of general health and psychosomatic-digestive complaints.

Further examination of the relationship between these two subscales of the Circadian Type Questionnaire and the amount of sleep residents reported having during the shift showed that only the rigidity/flexibility scale was predictive for the amount of sleep, in a sense that more rigid sleepers managed to take fewer naps during the shift than more flexible ones. This can explain the lack of predictive strength of vigorousness scale for cognitive performance after sleep loss, but it also gives an interesting insight into the possible mediating mechanism between the flexibility of sleep characteristic and the preserved cognitive performance after the shift, namely, flexible sleepers actually slept more during the shift (they managed to take up to four naps during the call). However, the need for a certain amount of sleep seems to be genetically hard-wired and stable, as are the individual sleep characteristics[20]. Thus, it is not likely that this finding could be put to practical use – there is little possibility that one can train him/herself to take more naps during the call if he/she is a rigid sleeper. It has been reported that the temporal stability of traits measured by the Circadian Type Questionnaire persists even after 9 years of shift work experience[31].

Overall, when it comes to retention abilities, our findings showed that not only sleep deprivation, but also the individual's age, in combination with his/her sleep characteristics, influenced cognitive performance after the 24-hour shift.

The situation was somewhat different with the digits forward and digits backward tests; multivariate repeated measures ANOVA with the time of testing as an independent variable and total number of recalled numbers forward and backward as dependent variables showed a significant main effect of the time of testing, but the separate tests showed that this main effect was driven by the rise (not fall) in working memory scores after the shift, while the efficacy of attention did not change after the shift (see Figure 2). The finding that retention capacities are reduced after the sleep loss, but that attention and working memory performance are either preserved or even enhanced might be somewhat counterintuitive. However, if we take a look at the type of tasks used as measures of different cognitive abilities, we can see that the Auditory Verbal Learning Test requires the longest time to complete, is repetitive in nature, and thus probably becomes boring easily. Digits forward and backward, on the other hand, are short tests, and the latter requires relatively high levels of cognitive engagement, which makes these tests less likely to induce the feelings of boredom and monotony among subjects. Wilkinson[32] has shown that complex, short and interesting tasks intrinsically encourage sleepy people to apply compensatory effort and perform normally, and this could explain our subjects' performance of digits span tests. Some other studies[33-35] have also indicated that monotonous tasks are most sensitive to fatigue and sleep, while the cognitive demanding ones are least sensitive. In a similar study on surgical residents[36], it was found that virtual reality-performance of high-fidelity virtual reality-tasks and objective alertness significantly improved in the post-call setting. It has already been shown that the ability to discover significant changes in medical variables was reduced in anesthesiologists after a night on call[37,38]. Our results are in accordance with these earlier findings and can be taken as a further warning for the field of anesthesiology particularly; if a practitioner has to engage in a long-term and monotonous task, e.g., patient monitoring, the likelihood of reduced performance is greater.

If possible, the repetitive, monotone tasks (e.g., patient monitoring) should be avoided at the end of the shift, as they increase the probability of making wrong decisions. However, the danger of falling asleep in monotonous circumstances extends beyond the performance lapses at the end of the night shift. Driving, especially on frequently taken routes, is a monotone activity *par excellence*; therefore, one should take extra caution when driving home. Other studies have shown that the car accident risk is 2.3 times higher after the 24-hour shift[39], that 66% of junior doctors working ≥40 hours a week felt close to falling asleep at the wheel in the past 12 months[40], and that 80% of emergency residents' near-crashes driving happened after the night-shift[41]. Reports on heavy vehicle accidents in the USA[42] have shown that the best predictors of fatigue-induced accidents were the amount of sleep in the preceding 24 hours and split-sleep patterns, which is typical for the anesthesiologists' 24-hour shifts.

As for the relation of individual sleep characteristics and the efficacy of attention, the findings are similar to the ones reported for retention capacities; neither rigidity nor vigorousness scale correlated with the digits span forward scores before the shift (as expected), while after the shift, subjects with higher scores on rigidity scale had lower performance on the efficacy of attention test. Contrary to that, characteristics of sleep did not correlate with working memory performance either before or after the shift. Again, the individual characteristics of sleep being hard-wired, we do not suggest that one could easily train him/herself to become a flexible sleeper; however, if the opportunity arises, and there are no emergencies, the chance for taking even a short nap should not be missed[43-46], as napping minimizes chronic partial sleep loss and improves alertness and performance.

There is probably no surprise in the finding that residents felt significantly sleepier after the shift; while a typical response before the shift was "I'm functioning on a high level, but not at my top performance. I am able to concentrate", a typical response after the shift was "I am relaxed and awake, but not completely". However, this subjective measure of sleepiness did not correlate with any of the objective measures of cognitive functioning. This is an important finding, as it reaffirms some previous notions regarding the inability of people to accurately assess their sleepiness/alertness level, i.e. subjective self-assessment generally underestimates fatigue and sleepiness[8,29,47]. A study in anesthesia residents by Howard *et al.*[48] has shown that they did not perceive themselves to be asleep almost half of the time they had actually fallen asleep and that they were wrong 76% of the time when they reported having stayed awake. Similarly, although some of our subjects reported being extremely sleepy, their scores did not show significant aberrations from the rest of the sample, while at the same time the subjects with lowest performance scores did not report being sleepier than the rest of the sample.

In our study, the residents were partially sleep deprived during a 24-hour shift. However, it must be mentioned that it is difficult to distinguish the effects of a recent 24-hour (short-term) sleep loss and the effects of a chronic partial sleep loss. Sleep after night work tends to be shorter than sleep after day work, which can lead to cumulative sleep deprivation[49,50]. Even when not on call, anesthesiologists often work long hours, with more or less regularly interpolated 24-hour shifts, when their sleep is limited and usually interrupted. One alarming finding[51] is that 64% of resident physicians were chronically sleep deprived. In line with this finding, a recent study[52] has shown a specific pattern of diastolic blood pressure (with the lack of diastolic blood pressure dipping), as well as an altered shape of diurnal salivary cortisol curve (with elevated night values) among staff anesthesiologists, which might indicate chronic stress and fatigue. This is important, as previous findings suggest that performance can be impaired with both short-term total sleep loss and chronic partial sleep loss[53,54]. Therefore, we must be cautious on interpreting our results as we cannot be sure whether the effects we found could be attributed only to 24-hour partial deprivation or to a combination of this short-term deprivation and a preceding cumulative sleep loss. On the other hand, it gives our results a greater external validity, as they might be a better indication of residents' performance in everyday conditions than the results of controlled laboratory studies of sleep deprivation.

Conclusion

A 24-hour shift does not affect all cognitive functions equally; the performance in short-term tasks that require concentration and working memory is not impaired, while the performance in long-term and monotone tasks shows decline after the shift, but this depends on some individual sleep characteristics, such as the ability to overcome sleepiness and rigidity of sleeping habits, and on age. Although results of our study must be interpreted cautiously due to the small sample size, our findings imply that age has an important impact on cognitive function after night shift even in the relatively age-homogeneous population of young anesthesiology residents.

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Sažetak

DOB I INDIVIDUALNE ZNAČAJKE SPAVANJA UTJEČU NA KOGNITIVNE SPOSOBNOSTI SPECIJALIZANATA ANESTEZIOLOGIJE NAKON 24-SATNE SMJENE

M. Tadinac, A. Sekulić, I. Hromatko, B. Mazul-Sunko i *R. Ivančić*

Istraživanja su pokazala da i rad u smjenama i deprivacija spavanja nepovoljno utječu na različite aspekte kognitivnog funkcioniranja. Cilj ovoga istraživanja bio je ispitati promjene u kognitivnom funkcioniranju i subjektivnoj pospanosti specijalizanata anesteziologije nakon 24-satnog dežurstva. Dvadeset i šestoro specijalizanata anesteziologije ispunilo je bateriju psihologijskih instrumenata na početku i na kraju dežurstva te upitnik s pitanjima o proteklom dežurstvu, Stanfordsku ljestvicu pospanosti i Upitnik cirkadijarnih tipova. Nakon dežurstva došlo je do značajnog pada kognitivnog uratka izmjerenog Auditivno-verbalnim testom učenja, koji je bio izraženiji kod starijih sudionika te onih s visokim rezultatom na ljestvici rigidnosti spavanja i niskim rezultatom na ljestvici prevladavanja pospanosti. Nisu utvrđene razlike u pamćenju brojeva unaprijed (koncentracija pažnje), dok je u pamćenju brojeva unatrag (radno pamćenje) čak došlo do poboljšanja uratka nakon dežurstva. Iako su na kraju dežurstva sudionici procjenjivali da su značajno pospaniji nego na početku dežurstva, ova subjektivna procjena pospanosti nije bila u korelaciji ni s jednom objektivnom mjerom kognitivnog uratka. Zaključno, uradak u kratkim zadacima koji zahtijevaju koncentraciju pažnje i radno pamćenje nije se pogoršao nakon dežurstva, dok je uradak u zadacima koji su dugotrajniji i monotoni bio značajno niži nakon deprivacije spavanja, pričem je to pogoršanje ovisilo o specifičnim individualnim značajkama spavanja te o dobi. Iznenađujuće je da je dob bila značajan čimbenik u smanjenju kognitivnog uratka nakon dežurstva čak i u relativno dobno homogenom uzorku mladih specijalizanata anesteziologije.

Ključne riječi: *Radni raspored, tolerancija; Stažiranje i specijalizacija; Anesteziologija; Kognicija; Pamćenje; Verbalno učenje; San, deprivacija; Stres, psihološki; Izgaranje na radnom mjestu*