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ORIGINAL

Night shift decreases cognitive performance of ICU physicians

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Take-home message: Residents and staff physicians from three ICUs were studied after a night of rest and after a night shift. Four key areas of cognitive ability were decreased after a night shift.

Electronic supplementary material
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Abstract *Background:* The relationship between tiredness and the risk of medical errors is now commonly accepted. The main objective of this study was to assess the impact of an intensive care unit (ICU) night shift on the cognitive performance of a group of intensivists. The influence of professional experience and the amount of sleep on cognitive performance was also investigated. *Methods:* A total of 51 intensivists from three ICUs (24 seniors and 27 residents) were included. The study participants were evaluated after a night of rest and after a night shift according to a randomized order. Four cognitive skills were tested according to the Wechsler Adult Intelligence Scale and the Wisconsin Card Sorting Test. *Results:* All cognitive abilities worsened after a night shift: working memory capacity (11.3 ± 0.3 vs. 9.4 ± 0.3; $p < 0.001$), speed of processing information (13.5 ± 0.4 vs. 10.9 ± 0.3; $p < 0.001$), perceptual reasoning (10.6 ± 0.3 vs. 9.3 ± 0.3; $p < 0.002$), and cognitive flexibility (41.2 ± 1.2 vs. 44.2 ± 1.3; $p = 0.063$). There was no significant difference in terms of level of cognitive impairment between the residents and ICU physicians. Only cognitive flexibility appeared to be restored after 2 h of sleep. The other three cognitive skills were altered, regardless of the amount of sleep during the night shift. *Conclusions:* The cognitive abilities of intensivists were significantly altered following a night shift in the ICU, regardless of either the amount of professional experience or the duration of sleep during the shift. The consequences for patients' safety and physicians' health should be further evaluated.

Keywords Cognitive · ICU · Physicians · Residents · Night shift · Sleep · Deprivation

Introduction

Chronic tiredness related to long working hours is common among intensive care unit (ICU) physicians [1, 2]. This phenomenon is aggravated by night shift-related acute fatigue and sleep deprivation. Tiredness is characterized by the reduced capacity to perform physical and mental tasks. The subject perceives himself/herself to have declined performance. It has also been clearly established that chronic tiredness negatively impacts patient safety [3, 4]. Medical errors related to tiredness were reported in the media for the first time in 1988 [5]. In the USA and Europe, numerous regulations were subsequently instituted to regulate the legal working hours of healthcare providers [6]. However, few studies have measured the effects of sleep deprivation on medical errors in the ICU [7–10]. A study performed more than 40 years ago reported that the rate of errors in interpreting electrocardiograms was increased by 50 % when interns were deprived of sleep [11]. The time to intubate the trachea was significantly longer during a night shift than during the day [12]. More recently, it has been shown that residents made 36 % more serious medical errors in the ICU when they frequently worked shifts of 24 h or more compared to when they worked shorter shifts [7]. Using a high-fidelity simulator, it was demonstrated that, during prolonged wakefulness, residents exhibited a marked deterioration in the clinical management of a simulated critically ill patient [10]. The impact of age on performance after a night shift has been poorly analyzed, particularly outside laboratory experimental conditions. Experience might minimize the risk of error, but competence likely does not replace the required rest. Indeed, it has been suggested that older persons are more likely than younger persons to be adversely affected by sleep deprivation [13]. A physician's own health may also be compromised by sleep deprivation [14]. Some authors have reported that occupational diseases are a consequence of physicians working night shifts [15]. Shift working is associated with a profound desynchronisation of circadian rhythm [16]. It has been suggested that sleep deprivation increases anxiety, irritability and depression scores [17, 18]. A study conducted in French ICUs concluded that 46 % of the intensivists surveyed suffered from burnout, and 24 % suffered from depression [1, 17]. Among the risk factors encountered, the number of monthly on-duties was associated with a high level of burnout [1].

In the general population, it has been shown that short-term sleep deprivation can impair vigilance, attention, executive functions, working memory, and higher cognitive abilities, such as decision making [19]. Few studies have evaluated cognitive performance in physicians after a night shift [20, 21]. Impairments may occur in several domains, including attention, cognition, motor skills, and mood [22]. A meta-analysis of many heterogeneous studies found that cognitive performance in physicians, particularly vigilance and memory, was affected by sleep deprivation [23]. In addition, the impact of chronic sleep deficiency on ICU residents was evaluated through a simple vigilance test after a night shift [24]. The decrease in neurobehavioral performance is exacerbated under these conditions [24]. Despite numerous studies of the effects of sleep deprivation on cognitive abilities, the literature still lacks sufficient data regarding intensivists.

Therefore, the main purpose of this study was to investigate the cognitive performance of intensivists after a night shift using validated and dedicated cognitive tests. The secondary goal was to determine the influence of physician experience and the amount of sleep during the night on these cognitive performance indicators.

Methods

Study population

We conducted a prospective, observational, comparative, randomized, cross-over study. Intensivists ($n = 51$) working in three intensive care units in North Hospital, Marseille, France, were prospectively included (staff physicians, fellows and residents). The study was approved by our local ethical committee.

Design

Each physician was his/her own control. Each subject participated to the study under two different conditions; once at the end of a night shift (NS) and once after a night of rest at home (NR). For each of the six groups (i.e. staff physicians/residents from the three ICUs), randomization using sealed envelopes was used to determine the order of the two conditions (NS first or NR first). These two evaluations were separated by a period of at least 7 days. The NR condition took place at least 3 days after the last on-duty shift. Night shifts occurred after 10 h of clinical activity which brings the total working time to 24 h. The duration of the night shift was 14 h (from 6:30 p.m. to 8:30 a.m.) in all the three ICUs. Physicians could have a nap during the day preceding the night shift.

Psycho cognitive assessment

All the evaluations were performed by the same psychologist (FM) in a quiet office between 10 a.m. and noon. Each assessment began with a demographic and lifestyle questionnaire and with self-assessments of attentional capacity or tiredness using visual analogue scales (VAS). Then, the participants completed four cognitive tasks, three of which were from the most recent version of the Wechsler Adult Intelligence Scale®—Fourth Edition (WAIS-IV) [25], and the fourth task assessed executive function and cognitive flexibility according to the Wisconsin Card Sorting Test (WCST) [26]. The cognitive battery of Wechsler (WAIS-IV) is the latest edited version (WAIS-IV available in French in 2011). It is the most used scale to evaluate cognitive performances in the general population in psychometric studies. This cognitive battery allows the calculating of 4 indexes from 3 subtests each time (i.e. verbal comprehension scale, working memory scale, processing speed scale, and perceptual reasoning scale). Because verbal comprehension is not altered by sleep deprivation, and in order to reduce the duration of participation to 30–40 min, we chose to study the other three cognitive indexes by means of a single subtest for each skill.

The following cognitive abilities were evaluated. First, working memory capacity (WMC—Digit Span Subtest of the WAIS-IV) assesses auditory short-term memory, attention and concentration. Second, perceptual reasoning capacity (Picture Completion or Block Design Subtests from the WAIS-IV) examines the ability to manipulate abstractions and rules and is a good indicator of general intelligence. Due to an important learning effect with these two tests, the same test was not used twice. Thus, picture completion and block design were used alternatively. These subtests, in the WAIS-IV, are equally effective in analyzing perceptual reasoning capacity. Each participant completed one test during the first evaluation and the other one during the second experimental evaluation. Alternatively, half of the "NS first" participants has begun with either picture completion or block design test and completed the other in the second session, likewise for "NR first" participants. We also verified that there was no significant difference in standardized scores depending on whether the participant had completed one or the other test after a night shift. Third, processing speed test (Coding Subtest from the WAIS-IV) assesses attentional and concentration capacities, as well as visual and motor abilities. And, fourth, cognitive flexibility (Wisconsin Card Sorting Test) measures the ability to shift strategies and move one's attention from one stimulus to another and is a good indicator of executive functions. There is a possible training bias with this test. It has been neutralized first through the randomization already done in the studied population (i.e. half of the participants completed this test for the first time during the "NS" examination and the other half for the first time in the "NR group"). Moreover, we paid attention to use different sorting rules between the two sessions.

Raw scores from the three WAIS-IV subtests were converted using WAIS software (standardized scores ranging from 0 to 20) according to age and sex. The additional subtest (Wisconsin Card Sorting Test) was scored on a scale of 64. The best score is 32, and the worst is 64.

According to the number of declared hours slept during NS, three sleep duration groups were used to investigate WMC, processing speed and cognitive flexibility abilities (2 h or less, more than 2 h but less than 4 h, and more than 4 h). To explore perceptual reasoning, which was not completed by five participants, the sample was split in two groups considering the median number of declared sleep hours during night shift (3 h).

Statistical analysis

VAS results were converted to quantitative variables (graduated from 0 to 10). To test our main hypothesis of impaired cognitive performance in the NS condition, ANOVA for repeated measurements with one within-subject factor (NS or NR) was performed for each cognitive ability. To test the effects of professional experience or sleep duration, we conducted ANOVA for repeated measurements with two within-subject factors (NS or NR and professional experience or sleep duration group). Whenever an interaction was significant, we isolated the interaction term by performing simple main effect analysis. Finally, to determine whether physician performance was related to individual perception of tiredness or attentional capacity, we conducted partial correlation analyses between each tested cognitive performance and self-reports of tiredness or attention. The statistical analysis was performed using SPSS 17.0® software, and $p < 0.05$ was considered to be significant.

Results

Intensivists ($n = 58$) working in three intensive care units of the North Hospital, Marseille, France, were prospectively screened (Fig. 1). Two staff physicians and two residents ($n = 4$) did not wish to participate, and three

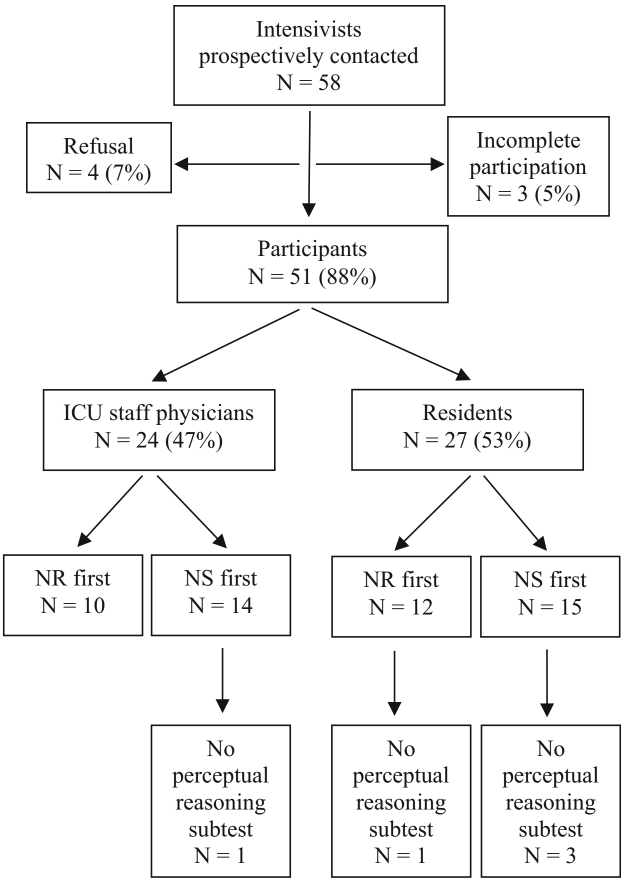

Fig. 1 Flow chart

participants had incomplete participation (one had no NR session, and two had no NS sessions). Finally, 27 residents and 24 ICU staff physicians (including fellows) ($n = 51$) completed the two parts of the study.

For the participating 51 physicians (Table 1), the average number of night shifts per month was 4.8 ± 1.4. In the NS group, the average number of declared hours of sleep during the previous night was 3.3 ± 1.5 h, and the average number of sleep interruptions was 2.2 ± 1.8. The physicians felt significantly more tired ($p < 0.001$) and sleep deprived ($p < 0.001$) at the end of the night shift (see Fig. E.1 in the supplemental appendix). Two ICU staff physicians and three residents reported having had a nap before the night shift.

Concerning the main results, all cognitive abilities declined after a night shift (Table 2). Among all intensivists and concerning the four studied skills, 75.8 % had lower performances after a NS (see Table E.1 in the supplemental appendix).

For the WMC, the cognitive skill was significantly deteriorated ($p < 0.001$); the performance was 9.5 % lower after a night shift. There was no significant interaction in terms of the change in performance between the NR or NS conditions and medical experience (Table 2). However, as shown in Fig. 2, in the NR condition, WMC was significantly higher among the ICU staff physicians compared with the residents (12.1 ± 2.5 vs. 10.6 ± 1.6; $p < 0.01$). For the WMC subtest (Fig. 3), there was a significant difference between NR and NS ($p < 0.001$) whatever the number of declared hours of sleep during the night shift. There was no difference between the forwards and backwards version of the WMC (digit span) subtest.

For information processing speed, the performance after a NS was also altered ($p < 0.001$), decreasing by 12.5 % compared with the evaluation after a NR (Table 2). As for WMC, there was no significant interaction between performance under the NR or NS conditions and medical experience. There was no difference between the ICU staff physicians and residents in terms of the information processing speed when the evaluation was performed after either a NS or NR (Fig. 2); the performance decreasing significantly in both groups. These performances were significantly lower after NS than NR ($p < 0.001$) whatever the number of declared hours of sleep (Fig. 3).

Perceptual reasoning also deteriorated after a NS ($p < 0.002$; Table 2). Performance was 6.5 % lower after a NS than after a NR. There was a significant interaction (Fig. 2) between the NR condition or the NS condition and medical experience ($p < 0.005$). We analyzed this interaction by conducting a simple main effect analysis (Table 2). The NR condition or NS condition had a significant main effect ($p < 0.001$), but medical experience had no main effect. For the NS condition, perceptual reasoning was significantly lower in the residents compared with the ICU staff physicians (8.7 ± 2.1 vs. 9.8 ± 2.3; $p = 0.043$) (Fig. 2).

Finally, for cognitive flexibility, the difference between the NS and NR conditions was not significant ($p = 0.063$) but lower for the NS condition (Table 2). For the NR condition, there was no significant performance difference for this ability between the ICU staff physicians and residents. However, decreased performance ($p < 0.05$) was observed in the residents only between the NR and NS conditions (Fig. 2).

Sleep deprivation altered cognitive function in the NS group (Fig. 3). The results showed a significant deterioration in WMC ($p < 0.001$), processing speed ($p < 0.001$) and perceptual reasoning ($p < 0.05$), regardless of the sleep duration during the shift. In contrast, the decrease in cognitive flexibility was only significant among the physicians who slept less than 2 h ($p = 0.026$). There was no significant interaction between experimental condition (NR or NS) and amount of sleep duration whatever the cognitive skill studied (Table 2).

A correlation analysis was performed between the self-reported tiredness or attentional abilities by physicians after their night shifts and their actual performance. The results showed no significant correlation between the

Table 1 Characteristics of the participants (mean ± SD excepting for gender and nap)

	ICU staff physicians ($n = 24$)		Residents ($n = 27$)		ICU staff physicians vs residents (p value)
	NR first ($n = 10$)	NS first ($n = 14$)	NR first ($n = 12$)	NS first ($n = 15$)	
Men/women, *n* (%)	5 (50 %)/5 (50 %)	10 (71 %)/4 (29 %)	5 (42 %)/7 (58 %)	3 (20 %)/12 (80 %)	$p < 0.018$
Age (years)	36.3 ± 7.0	38.2 ± 7.6	26.5 ± 1.7	27.4 ± 1.6	$p < 0.001$
Number of years in ICU specialty	7.6 ± 5.3	9.3 ± 7.7	2.4 ± 0.8	2.8 ± 0.9	$p < 0.001$
Monthly average number of night shifts	5 ± 2	4.4 ± 1	4.7 ± 1	5.2 ± 1.6	ns
Duration of sleep before the evaluation NR	6.5 ± 0.7	6.5 ± 1.4	6.2 ± 0.5	6.5 ± 1.1	ns
Average number of declared hours of sleep during the night shift	4.5 ± 1.5	3.9 ± 1.5	2.4 ± 1.5	2.8 ± 1	$p < 0.001$
Number of days since the last night shift (NR)	9.8 ± 10.4	8.6 ± 9.8	6.5 ± 3.8	6.2 ± 5.1	ns
Average number of phone wakes up over the night shift	0.9 ± 1.4	1.8 ± 1.3	2.2 ± 1.4	3.3 ± 2.1	$p < 0.002$
Average number of stand ups during night shift	0.3 ± 0.5	0.4 ± 0.5	1 ± 0.9	1 ± 0.9	$p < 0.001$
Average number of coffee during the night shift	2.4 ± 1.1	2 ± 1.2	1 ± 1.2	1 ± 1.2	ns
Number of physicians who had a nap before the night shift	$N = 0$	$N = 2$	$N = 0$	$N = 3$	

There was no significant difference between NR first and NS first conditions in each group (staff physicians or residents)
NS after a night shift, *NR* after a rest night, *ns* non-significant

Table 2 Cognitive performances of intensivists after night shift or rest night

	Rest night (NR)	Night shift (NS)	p value (NR or NS)	Interaction NR or NS (factor 1)* ICU staff physicians or residents (factor 2)	Interaction NR or NS* sleep duration
Working memory capacity (rated on 20)	11.33 ± 0.31	9.41 ± 0.31	$p < 0.001$	ns	ns
Processing speed (rated on 20)	13.47 ± 0.43	10.96 ± 0.34	$p < 0.001$	ns	ns
Perceptual reasoning (rated on 20)	10.63 ± 0.27	9.30 ± 0.34	$p < 0.002$	NR or NS* residents or staff Physicians, $p < 0.005$[a] Main effect of 1, $p < 0.001$[a] Main effect of 2, ns[a]	ns
Cognitive flexibility (marked on 64, the best score is 32 and the worst 64)	41.23 ± 1.16	44.16 ± 1.27	$p = 0.063$	ns	ns

p values of main effect (NR or NS) and interactions effects (NR or NS and physicians experience or sleep duration during night shift)
ns non-significant
* Interaction between the two variables
[a] We broke apart every significant interaction to analyze the simple main effects

self-reports and the cognitive evaluations (data not shown).

Discussion

We report here that the cognitive abilities of all ICU physicians decreased after a night shift. There was no significant difference in terms of level of cognitive impairment between the residents and ICU physicians. Our results emphasize the reality of cognitive impairment using robust methodology.

We have chosen to study the cognitive consequences of acute tiredness specifically in ICU physicians because intensivists are facing their entire careers arduous night shifts, with a need for thinking capabilities and efficient and speedy decision making. Literature is poor regarding this subject. Moreover, previous studies involved only residents [27], were related to the consequences of chronic sleep deprivation [24] or were performed in a laboratory [28]. To the best of our knowledge, no study had compared

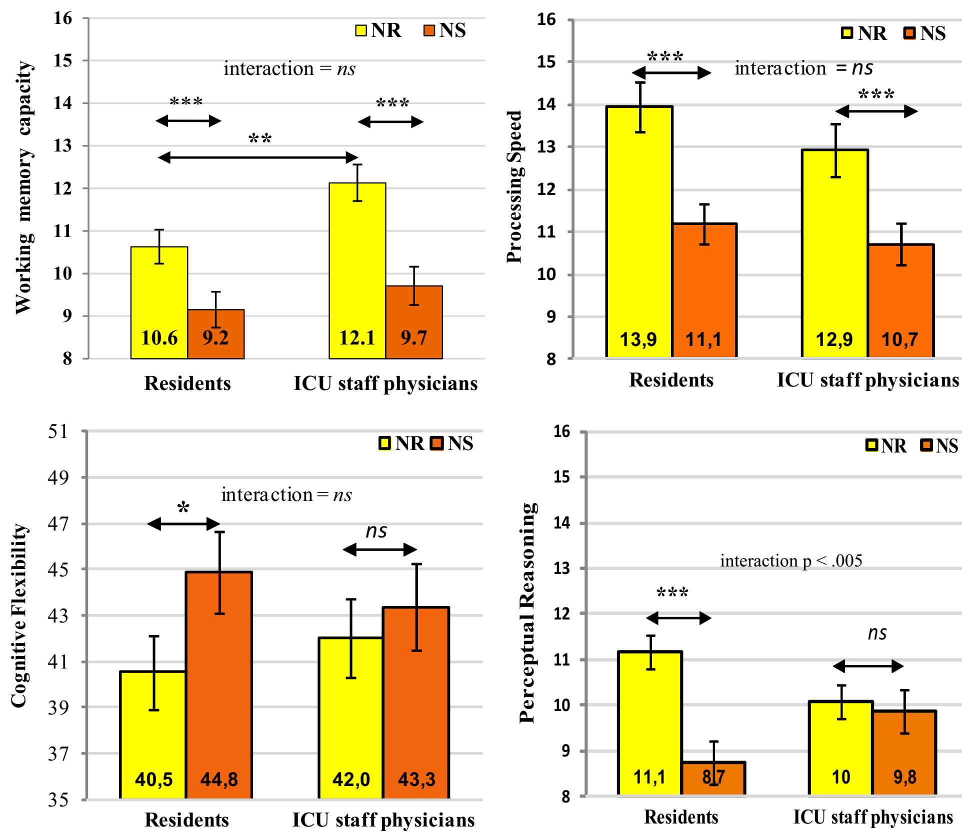

Fig. 2 Effect of medical experience (residents vs. ICU staff physicians) on cognitive abilities (processing speed, working memory capacity, cognitive flexibility and perceptual reasoning) after night shift (*NS*) or night rest (*NR*). (*ns* non-significant; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$). Interaction tested, condition (NR or NS) and medical experience (ICU staff or resident)

ICU residents and ICU staff physicians regarding the differential impact on cognitive alterations secondary to sleep deprivation. Thus, we have chosen to assess cognitive performances using sophisticated validated batteries (WAIS-IV [29] and WCST [30]). We found that intensivists were unable to evaluate their tiredness and attention capacity. They moderated their own loss of cognitive performance. If a physician is unable to evaluate his/her tiredness and minimizes its impact, he/she could neglect the risks for his/her own health and patients.

Very few studies have examined the influence of age on cognitive alterations secondary to sleep deprivation. Several factors could be in favor of better performance in older physicians. First, seniors are sleeping on average more than residents during night shifts (as in the present study). Moreover, physiologically with age, the need is less in terms of hours of sleep [31], and this may help a more rapid recovery. Second, the experience can also help to go back to sleep easily after being awakened as nervous tension falls more quickly with expertise. Finally, it is described that age reduces the "strategic repertory" to solve a task [32]. Indeed, having successfully tested for many years an effective way to solve a problem, an older person will disperse less to find alternative solutions. Older persons may be less strategically flexible but faster to implement the strategy that works best for them, which can preserve their performances in situations of lack of sleep. Interestingly, for WMC, speed processing and cognitive flexibility, we did not find a significant interaction between the cognitive deterioration after a night shift and physician experience. In our study, experience does not seem to protect even the most experienced intensivists, although the average sleep time during the night shift was greater than that for the residents.

It might be difficult to correlate our results exactly with real clinical performances or quality of care, but this was not our aim. Even if the tested skills significantly decreased after a night shift, our results do not allow us to evaluate the impact regarding patient quality of care. Our study shows a significant decrease in cognitive performance of intensivists after a night shift. However, it remains in the mean ± 1 SD of the performance of their reference population. This information is particularly interesting and reassuring since it means that patients' safety might not be compromised. However, the design of our study cannot demonstrate any relationship between these decreased performances and a loss of quality of care. The implications of physician sleep debt on patient safety should be profound [33]. However, a meta-analysis of seven studies did not report any significant association between the doctor's tiredness and patient mortality [34]. Hence, the debate continues regarding the appropriate timing of physician work hours and patient safety. A prospective, randomized study comparing extended work

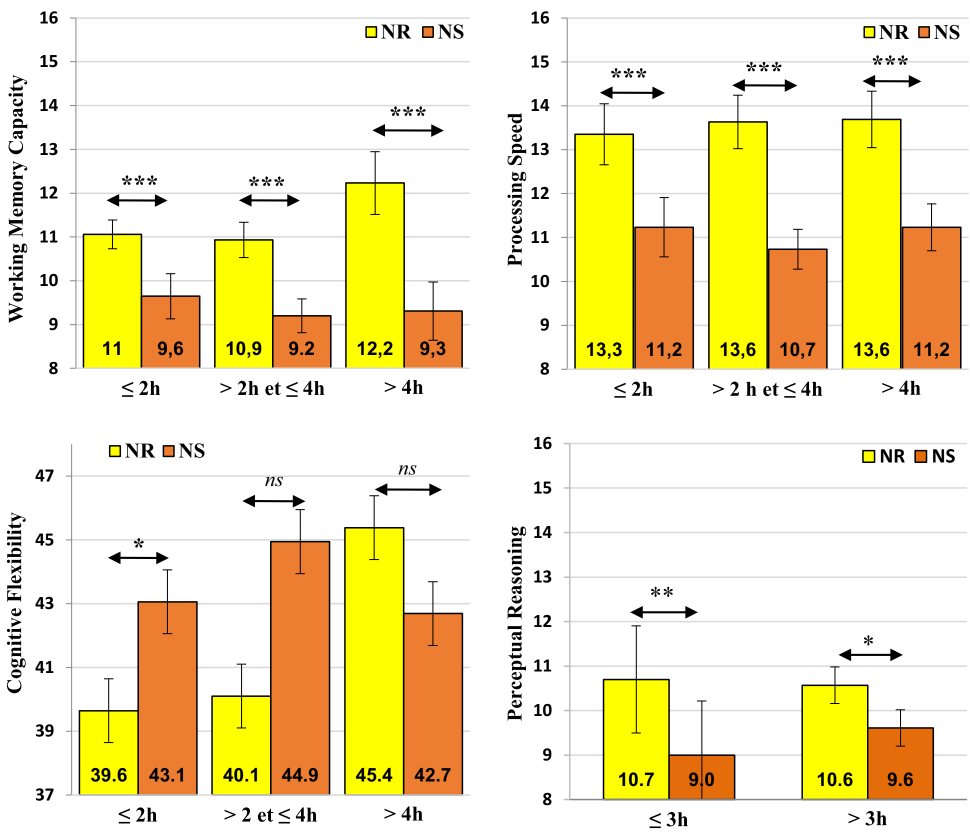

Fig. 3 Cognitive performances impairment (working memory capacity, processing speed, perceptual reasoning and cognitive flexibility) depending on the amount of sleep during night shift. (*NS* night shift; *NR* night rest; *ns* non-significant; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$)

shifts and reduced work time has demonstrated that residents made substantially more serious medical errors when working extending times [7]. However, the link between sleep deprivation and patient morbidity from medical errors remains unproven. It has been shown that work hour limits for residents decrease burn out; however, such changes did not change either the total hours of sleep after implementation or the rates of medication errors, resident depression or resident injuries [35].

Our study has some limitations. First, the studied population was broadly young. Indeed, the average age of intensivists in France is 51 years [36]. A larger age gap between senior physicians and residents could have magnified the cognitive performance differences between the two groups. Second, for practical reasons (in terms of the time required to complete the tests, particularly after a night shift), we chose to evaluate only one subtest of each WAIS index, excluding Verbal Comprehension, which seemed unlikely to be affected by a night shift. Third, the night shifts might have been unequal in terms of workload, quantity or quality of sleep and sleep duration during the night preceding the night shift. This point is difficult to assess because a rest night might be of poor quality in terms of sleep duration. In our study, however, all physicians and residents from the three ICUs had the same workload on the day of NS evaluation. Moreover, sleep loss in the clinical situation is usually acute sleep deprivation superimposed on chronic sleep loss. However, a relatively large cohort of physicians was analyzed, allowing us to temper the influence of these parameters.

The debate continues, but there is now a strong trend towards limiting physicians' working hours, at least in Europe and the USA. Our study extends the physiological knowledge on the lack of sleep among intensivists after a night shift, and it challenges the current knowledge of the cognitive consequences of acute tiredness. We have shown a significant decrease on skills partially involved in decision-making capacities through psychometrically internationally validated tests. Further studies are needed to clarify when the cognitive performances of ICU physicians decline during a night shift, as well as the possible consequences for ICU patients. Indeed, the possible deleterious consequences for ICU patients remain to be studied. It is also crucial to optimize the organization of physician working hours [37] and to study the consequences of sleep deprivation on the health of ICU physicians.

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Compliance with ethical standards

Conflicts of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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