Contrasting effects of work schedule changes and air traffic intensity on ATCOs' fatigue, stress and quality of life

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Abstract. Introduction. Shiftwork and task load are the most researched factors known to impact air traffic control performance and safety. **Research question.** An experimental shift schedule and reduced traffic intensity were expected to improve sleep, alertness, strain, and work-life quality. **Method.** 57 ATCOs completed a survey to test the effects of an initial and an experimental work-schedule, and of intense vs lower traffic. **Results.** More beneficial effects occurred for reduced aircraft traffic than for schedule change, and they were reduced on morning shifts concerning sleep duration, daytime alertness, and family life quality. **Discussion.** Work organization and workload would affect sleep and alertness while shift would directly impact family life quality. **Conclusion.** This retrospective investigation is actually completed by a prospective investigation.

Keywords: Shift organization, Workload, Sleep, Alertness, Work life and Family life Quality

Introduction

Shiftwork and task load are the most researched factors known to impact air traffic control performance and safety. Air traffic controllers (ATCOs) generally work rotating shifts to provide continuous air traffic control. This work organization requires individuals to work at times when they would normally be sleeping and exacerbates fatigue generated by air traffic control that requires constant concentration (Federal Aviation Administration FFA, 2009). The FAA defined fatigue as "a condition characterized by increased discomfort with lessened capacity for work, reduced efficiency of accomplishment, loss of power or capacity to respond to stimulation, and is usually accompanied by a feeling of weariness and tiredness" (Salazar, 2007, p. 1). Fatigue has been identified as a potential contributing factor in several operational errors (FFA, 2009, 2013), and of 21 percent of aviation accidents (Wang, Xie, Chin, Fu, 2013). Task load is the demand imposed by the air traffic control task and is mostly assessed in terms of workload, i.e. the controller's subjective experience of that demand. The relationship between task load and worklaod is influenced by a number of internal factors (Loura, 2014). Air traffic control workload is generally defined by traffic load or density (i.e., the number of aircrafts), and by the capacity of the operator to meet those demands. With rapidly increasing air traffic density, ATCO workload is an issue of even greater importance. The present study investigated the effects shift-schedule and workload on work-related and work-independent measures (i.e. sleep, fatigue, work strain, quality of work life and life beyond work) in ATCOs working in an en route control centre.

Assessing the controller workload and predicting when this workload will exceed safe limits are important issues for air traffic safety and security. Comprehensive descriptions of controllers' work and their cognitive aspects have been proposed by job analyses and by modeling controller working process or specific performance features (see for instance Kallus et al, 1999). It is generally admitted that ATCO workload depends largely on the number of flights to be handled in a given time interval. Additional workload factors include traffic complexity, such as number of flight altitude transitions, direction variations, trajectory uncertainty, proximity of aircraft, weather conditions (Corver, Unger, Grote, 2016; Hilburn and Jorna, 2001). The controllers' capacity to meet these task demands (select priorities, manage their cognitive resources, regulate their performance) also contributes to this relationship (Loft, Sanderson, Neal, Mooij, 2007). Psychophysiological and neural correlates, but also self-reported workload measures have been shown to be associated with air traffic load (Collet, Averty, Dittmar, 2009). Task load (accomplishing task requirements) has also a direct influence on other dimensions and in particular on fatigue, and may be a predictor of fatigue (but see also Edwards et al., 2012, 2017).

Fatigue is a consequence of many aspects of work and in particular of the amount of time that an individual spends working (i.e. work hours) and the way in which working time is arranged (i.e. shift schedules) (Dawson & Fletcher, 2001; Mélan, Galy, Cariou, 2007). The impacts of such working schedule parameters on fatigue, and as a consequence on workplace safety, well-being and health have been largely described (Costa, 2000; Folkard and Tucker, 2012; Rose, Jenkins, Hurst, 1978). Briefly, backward- compared to forward-rotating shift-systems, and long (i.e. 12h) compared to short (i.e. 8h) shifts are associated with a greater sleep debt (Monk, Folkard, Wedderburn, 1996). Significant predictors of fatigue include sleep length, shift duration, night shift and workload ratings (Dorrian, Baulk, Dawson, 2011). Conversely, aligning work and circadian time in shift workers improved sleep and reduce circadian disruption (Vetter, Fischer, Matera, Roenneberg, 2015). Further, faster rotations are recommended as they limit exposure to night work and may serve to decrease any cumulative effects. The FFA (2009) identified counter clockwise shift rotations, and scheduled overtime among those factors that could create potential fatigue conditions for air traffic controllers. To avoid extreme fatigue and to mitigate its impact on controller performance, countries and companies regulate for instance controller work hours, the minimum rest periods between shifts, the number of controllers assigned to a shift (in particular the nigh-shift), and recuperative breaks. More appropriate scheduling of controller policies were also introduced in Europe to reduce the occurrence of minor air traffic control incidents and to deal with increases in air transport intensity, more especially during the more busy summer period. The extent to which the new policies impact ATCOs' fatigue, and thus controller performance, have not yet been determined, due in particular to the absence of accurate metrics and of systematic controlled studies (FAA, 2013).

Shift system changes, in particular from a typical 3-shift system to a densified work schedule, have been described in industrial sectors with continuously-working equipment or ongoing processes (for instance Rosa, Wheeler, Warm, Colligan, 1991; Paley, Price, Tepas, 1998). The results of these studies may not apply to the air traffic control sector submitted to specific constraints. Indeed, air traffic flow differs markedly between day- and night-shifts, and several traffic peaks occur on day-time, as a consequence mostly of local or intra-continental flights. Further, ATCOs' fatigue is not only determined by factors related to work organization (i.e. shiftwork, night-shift, workload, type of work performed, break frequency and duration), but also by the work environment (ambient lighting, noise,..) and by several work-independent factors, such as sleep disorders, circadian rhythm, emotional stress and domestic and social responsibilities, in addition to personal characteristics and age (Nealley & Gawron, 2015).

The present study focused on the impacts work-organization and traffic intensity in ATCOs working in an en route control centre. The shift-work schedule was changed by a Ministerial Decree in order to enable a better fit with high traffic load occurring more especially on day-shifts and during the summer period. Therefore, more controllers were assigned to the control room during day-time traffic peaks by introducing an additional shift, by delaying the beginning and end of shifts for part of the team members, and by reducing the mean shift duration to keep the annual work time constant. The first aim of the study was to test the effectiveness of the modified work schedule in terms of controller fatigue, strain and quality of life in the modified compared to the initial work schedule. The second aim was to test the influence of traffic load on these dimensions, by comparing, in the initial shift-schedule condition, ATCOs' responses in regard to a high-traffic period and to a period of relatively reduced air traffic. In the absence of a universal metric of these dimension self-reported measures were used as they may be regarded as a compound measure reflecting both the effects of control strategies to meet task demands and of ATCOs' momentary functional state. Given the multiple determinants of fatigue this dimension was assessed by subjective measures of sleep satisfaction, sleepiness and alertness, and by a more objective measure (reported sleep duration). Strain was assessed together with workload measures and quality of life was explored in the work and non-work domains. Both the experimental shift schedule and reduced traffic intensity were expected to have beneficial effects on fatigue, strain, and work life quality, as reduced workload and time-on-shift have been shown to be associated with decreased fatigue and tension and improved work-life quality (Akerstedt, Knutsson, Westerholm, Theorell, Alfredsson, Kecklund, 2004; Bültmann, Kant, van den Brandt., Kasl., 2002; Dorian et al., 2011; Mélan et al, 2007; Rosa et al., 1991). The beneficial effects were expected to be significantly less marked for night-shifts due to the nocturnal nadir of biological rhythms and the long duration of this shift (Monk et al. 1996), and for the morning-shift as a consequence of reduced sleep duration typically associated with early starting morning shifts (Tucker, Smith, Macdonald, Folkard, 1998). In contrast, quality of life in the non-work domains was expected to be decreased with the experimental shift-schedule, as the introduction of an additional shift in the work cycle would make ATCOs less available for family-life.

Method

57 (29.8% females) ATCOs, aged 38.9 (range 28 to 56), and operating commercial flights for a mean of 11 years, volunteered to participate in the study (21% of the ATCOs working in the centre). They worked in 12-member teams a 12-day work cycle in an en route control centre in the North-East of France. The work schedules were modified by a decree (17th July 2015) in order to have more controllers in the control room during day-time traffic peaks. The initial work cycle (Table 1) alternated three work days (morning 1, day, evening 1), three rest days, and again three work days (morning 2, evening 2, night) and three rest days. In the modified work-cycle the shifts were organized in the same order, except that i) an additional shift called "experimental shift" replaced a day-off in the middle of the cycle, ii) shift-duration was modified (increased by one and two hours for the two morning-shifts, and decreased by two hours for the day shift lasting initially 10h, and iii) 1/3 of the team members started and ended the evening- and night-shifts 2 and 3 h earlier while the duration of these shifts remained unchanged (i.e. 10h for the night-shift).

Table 1. Number of ATCOs in the control room and shift start and end (between brackets) for each shift of the initial and experimental work schedule.

	Initial work schedule		Experimental work schedule	
Morning 1	2	[06:00 ; 16:30]	12	[06:00 ; 14:00]
	10	[06:00 ; 14:00]		
Morning 2	2	[06:30 ; 15:00]	4	[06:30 ; 15:00]
	10	[07:00 ; 15:00]	8	[07:00 ; 15:00]

Day	2	[07:30 ; 18:30]	12	[10:00 ; 18:30]
	8	[08:00 ; 18:30]		
	2	[08:00 ; 19:00]		
Experimental day			2	[07:00 ; 15:00]
			2	[08:00 ; 16:00]
			2	[08:30 ; 16:30]
Evening 1			2	[13:00 ; 21:30]
	2	[09:15 ; 19:45]	2	[15:00 ; 22:00]
	10	[10:00 ; 23:00]	2	[15:00 ; 22:30]
			6	[15:00 ; 23:00]
Evening 2			2	[12:00 ; 20:30]
	2	[11:30 ; 20:45]	2	[15:15 ; 23:00]
	10	[15:15 ; 23:45]	2	[15:15 ; 23:30]
			6	[15:15 ; 23:45]
Night	2	[19:00 ; 06:00]	2	[16:30 ; 00:30]
	10	[19:45 ; 06:00]	10	[19:45 ; 06:00]

ATCOs completed outside working time or during a break in about 15 to 20 minutes an on-line survey that was available over a 5-week period in 2016 (13th January to 19th February). The survey included three questionnaires, each assessing retrospectively a 2-month period of interest, i.e. summer 2014 (intense traffic, initial work-schedule), autumn 2014 (lower traffic, initial work schedule), summer 2015 (intense traffic, experimental work-schedule). The participant completed the three questionnaires successively on a single session and he/she had not the possibility to switch back to previous pages.

The three questionnaires were identical and each was comprised of 24 items that were rated on 6-point scales (from 1 *"not satisfactory at all" to 6 "very satisfactory", or "I strongly disagree" to I strongly agree")*. This was an attempt to reduce potential response bias around the mid-point of the scale. In order to limit the questionnaires' length, work schedules were grouped into "morning shift" (M1, M2), "afternoon shift" (DE, E1, E2) and "night shift" (N) respectively. Individual items were rated either once (overall measure over the research period; 5 items), three times (for each of the three shift types considered; 6 items), or four times (for each shift type and on days off; 13 items). Altogether, for each participant 75 data were collected on each research period and a total of 225 data for the entire research protocol.

Sleep and fatigue *(13 items)*: The different components of fatigue were assessed by thirteen items that were rated separately for each shift and, when useful, also for days off.

- Six items assessed sleep duration of the nocturnal and of the diurnal sleep (after night shifts) and of the naps and two items assessed satisfaction with sleep duration and quality.
- Four items assessed alertness upon awakening, on shift-beginning and shift-end, and during daily non-work activities.
- One item assessed sleepiness, expressed by the frequency of moments of fatigue during each shift.

Strain and workload *(4 items).*

- Two items explored the level of strain on shift-beginning and shift-end.
- Two items assessed workload separately for each shift and as an overall measure across the work period respectively.

Quality of life (7 items).

- Three items explored the quality of life in the non-work domain, separately for each shift (quality of family life, atmosphere, possibilities to combine work and non-work activities).
- Four items assessed ATCOs' perceptions of their work life quality across a research period (work-life quality, atmosphere among team members, work schedules, breaks).

Repeated measure ANOVAs of shift schedule x shift, and thereafter of traffic intensity x shift were used to analyze all dependent variables except for sleep length analyzed with Friedman's test. For post-hoc analyses Bonferoni's test and Wilcoxon's test were used respectively.

Results

Effects of work-schedule

Mean sleep duration and subjective ratings of sleep quality and duration according to traffic intensity and shift are summarized in Table 2. The table indicates the total number of hours a sleep over a 24-h period, e.g. the nocturnal sleep and day-time naps. The latter concerned 56% of ATCOs. When ATCOs worked the initial shift schedule, the mean sleep duration varied significantly according to the shift worked (KHi2=123.99, $p < 10^{-3}$), with significant less sleep prior a morning shift compared to afternoon shifts, night shifts and days off ($p < 10^{-3}$) and prior afternoon shifts compared to night shifts ($p < 0.007$) and days off ($p < 0.009$). Comparable results were obtained with the experimental shift schedule (KHi2=103.99, $p < 10^{-3}$), with again less sleep prior morning shifts compared to all other shifts and days off (in all cases, $p < 10^{-3}$) and more sleep prior night shifts than prior days off ($p < 0.007$). Pairwise comparisons separately for each shift revealed significant more sleep prior morning shifts with the experimental work organization ($p < .003$) and a similar tendency for sleep prior days off ($p < .055$). Controllers' were however not more satisfied with their sleep duration and sleep quality when working according to the new shift-schedule. Both subjective measures varied, however, according to the shift worked (duration: $F1,55 = 183.18$, $p < 10^{-3}$; quality $F1,55 = 130.88$, $p < 10^{-3}$). As expected sleep duration and quality were rated significantly less satisfactory prior morning shifts (all comparisons $p < 10^{-3}$) and significantly more satisfactory prior days off (all comparisons $p < .002$). Interestingly they appreciated also more sleep duration proceeding night shifts rather than afternoon shifts ($p < .018$). A similar pattern of results was obtained for self-reported alertness upon awakening (Table 2), with no effect of work organization but a significant effect of shift ($F1,55 = 138.83$, $p < 10^{-3}$). The latter resulted from lowest alertness when ATCOs woke up on days they had to work morning shifts (all comparisons $p < 10^{-3}$) and highest when they started days off (all comparisons $p < .001$).

Analyses of mean scores relating to ATCOs' perceptions while they were on-job revealed that alertness on shift beginning was affected both by work organization ($F1,55 = 5.23$, $p < .026$) and shift ($F2,55=48.15$, $p < 10^{-3}$). Alertness was higher with the initial shift schedule what was quite unexpected, but again lower when starting morning shifts rather than afternoon and night shifts. In contrast, on shift-end ATCOs' alertness level was independent of shift schedule and shift. On contrary, a significant effect of shift on sleepiness ($F1,55 = 141.45$, $p < 10^{-3}$) indicated that moments of fatigue occurred more frequently during morning and night shifts than during afternoon shifts ($p < 10^{-3}$). Elsewhere, the work organization did not affect ATCOs perceived stress and tension, and the effect of shift evidenced on the beginning ($F1, 55 = 5.08$, $p < .028$) and end of shifts ($F1,55 = 4.61$, $p < .036$) yielded no significant differences between shifts when post-hoc comparisons were performed. However, the initial shift schedule was associated with significant higher workload, both when workload was assessed as an overall measure across the research periods (t-Test, t1,55 = 4.09; $p < 10^{-3}$), and according to the shift worked (F1,55 = 7.52, $p < .008$). Workload also differed between shifts (F1,55 = 14.91, $p < 10^{-3}$); it was lower on night shifts compared to morning shifts ($p < .001$) and afternoon shifts ($p < 10^{-3}$).

Table 2. Mean number of hours asleep and mean scores of alertness, tension and quality of life dimensions for each of the three research periods considered. Items were rated separately for each shift and for days off if useful. Standard deviations figure between parentheses.

	Initial shift schedule, High traffic load,				Initial shift schedule, Lower traffic				Exerimental shift schedule High traffic load			
	Mor-ning	After-noon	Night	Day off	Mor-ning	After -noon	Night	Day off	Mor-ning	After-noon	Night	Day off
Sleep (hours)	6h15	8h50	8h60	8h47	6h19	8h56	8h70	8h48	6,29	8,53	8,91	8,64
Sleep duration	2.43 (1.19)	4.30 (1.13)	4.59 (1.15)	5.05 (.88)	2.78 (1.23)	4.60 (1.05)	4.87 (1.02)	5.21 (.78)	2,57 (1,21)	4,35 (1,21)	4,63 (1,20)	4,92 (1,02)
Quality	2.80 (1.31)	4.62 (1.21)	4.69 (1.19)	5.16 (.94)	3.30 (1.32)	4.78 (1.07)	4.82 (1.06)	5.23 (.80)	2,57 (1,21)	4,35 (1,22)	4,62 (1,20)	4,92 (1,03)
Alertness (awakening)	2.80 (1.24)	4.10 (1.27)	4.39 (1.26)	4.76 (.93)	3.08 (1.32)	4.76 (1.11)	4.89 (1.05)	5.23 (.83)	3,03 (1,33)	4,462 (1,25)	4,55 (1,22)	4,96 (0,93)
Alertness (shift beginning)	3.00 (1.41)	4.44 (1.21)	4.35 (1.24)	/	3.05 (1.49)	4.64 (1.11)	4.58 (1.14)	/	2,85 (1.31)	3,98 (1.30)	3,94 (1.35)	
Alertness (shift end)	2.14 (1.16)	3.11 (1.33)	2.08 (1.36)	/	2.73 (1.15)	3.87 (1.16)	2.67 (1.45)	/	2,17 (1.18)	3,13 (1.32)	2,11 (1.38)	
Alertness (daily activities)	2.67 (1.28)	4.05 (1.35)	4.05 (1.26)	4.89 (.90)	4.07 (1.49)	4.59 (1.35)	4.64 (1.42)	5.23 (.83)	3,00 (1,26)	4,17 (1.16)	4,02 (1,39)	4,98 (1.02)
Fatigue on shift	4.85 (1.23)	3.57 (1.33)	4.48 (1.71)	/	4.21 (1.48)	2.91 (1.26)	3.73 (1.65)	/	4,46 (1.30)	3,76 (1.48)	4,18 (1.582)	
Tension on shift beginning	2.73 (1.16)	2.76 (1.64)	2.51 (1.53)	/	1.91 (1.06)	1.76 (0.95)	1.87 (.98)	/	2,57 (1.45)	2,31 (1.40)	2,35 (1.39)	
Tension on shift end	3.39 (1.79)	3.23 (1.78)	2.96 (1.72)	/	2.32 (1.34)	2.32 (1.32)	1.45	/	2,93 (1.65)	2,80 (1.60)	2,70 (1.67)	
Workload (shift)	4.46 (1.42)	4.53 (1.34)	3.91 (1.50)	/	2.67 (1.22)	2.73 (1.24)	2.46 (1.11)	/	3,67 (1.35)	3,72 (1.31)	3,5 (1.36	
Family life quality	3.27 (1.48)	4.26 (1.24)	4.07 (1.45)	5.23 (.83)	3.55 (1.37)	4.48 (1.27)	4.26 (1.35)	5.33 (.83)	3,37 (1.02)	4,15 (1.28)	3,89 (1.45)	5,13 (1.08)
Family life atmosphere	3.87 (1.52)	4.46 (1.29)	4.40 (1.43)	5.26 (.82)	4.07 (1.50)	4.59 (1.35)	4.46 (1.42)	5.35 (.88)	3,74 (1.48)	4,28 (1.29)	4,03 (1.45)	5,15 (1.16)
Work/non work activities	3.39 (1.52)	3.84 (1.43)	3.80 (1.35)	/	3.80 (1.48)	4.07 (1.33)	4.10 (1.27)	/	3,370 (1.51)	3,78 (1.19)	3,52 (1.33)	

Quality of life at work and in non-work domains (Table 2) did not differ according to the shift schedule, while an effect of shift occurred for the quality (F1, 55 = 95.20, $p < 10^{-3}$) and the atmosphere of family life (F1 55 = 58.64, $p < 10^{-3}$). Post-hoc comparisons indicated that both measures were decreased on days where ATCOs worked in the morning (all comparisons $p < .002$), and conversely significantly improved on days off (all comparisons $p < 10\text{-}3$). It is noteworthy that, in addition, ATCOs rated the family life atmosphere at a comparable low level on days they worked morning and night shifts. Overall assessment of work life (Table 3) indicated that work life quality (t1,55 = 4.50; $p < 10^{-3}$) and the atmosphere between team members ($t1,55 = 3.81$; $p < 10^{-3}$) improved with the new work organization. Quite contradictory, ATCOs did not rate the new work organization as being more satisfactory than the initial one.

Table 3. Mean scores of overall workload and quality of life dimensions rated once as an overall measure for each of the three research periods considered. Standard deviations figure between parentheses.

	Initial shift schedule, High trafic load,	Initial shift schedule, Lower trafic	Exerimental shift schedule High trafic load
Worload	5.11 (.97)	3.16 (.95)	5,07 (0.97)
Work life quality	3.23 (1.26)	4.64 (.86)	4,17 (1.22)
Work atmosphere	3.82 (1.34)	4.88 (1.03)	4,67 (1.23)
Shift-schedule	3.57 (1.36)	4.48 (1.10)	3,76 (1.36)
Work breaks	3.88 (1.28)	4.84 (.93)	4,29 (1.24)

Effects of traffic load

When workload was reduced, ATCOs' mean sleep duration varied significantly according to the shift worked (khi2 = 123.63, $p < 10^{-3}$), with significant less sleep prior morning shifts compared to the other shifts and days off ($p < 10^{-3}$) and more sleep prior night shifts compared to days off ($p < 0.003$). Comparisons between periods with high and lower traffic indicated a comparable number of hours asleep on both periods. According to subjective measures, controllers' were more satisfied with the duration ($F1,55 = 17.21$, $p < 10^{-3}$) and the quality ($F1,55 = 6.07$, $p < .017$) of their sleep when they had to control less airplanes. A significant cubic trend for shift ($F1,55 = 216.16$, $p < 10^{-3}$) indicated that ATCOs were more satisfied with the sleep duration on days off compared to all work shifts (p < 10-3), prior night and afternoon shifts compared to morning shifts and on night compared to afternoon shifts ($p < .018$). A similar cubic trend for sleep quality ($F1,55 = 155.01$, $p < 10^{-3}$) indicated that ATCOs were more satisfied with their sleep prior days off ($p < 10^{-3}$ for all comparisons) and less satisfied when working morning shifts rather than other shifts ($p < 10^{-3}$). Further, when the traffic load was reduced ATCOs rated their alertness upon awakening at a higher level ($F1,55 = 24.31$, $p < 10^{-3)}$ and differently according to the shift worked ($F1,55 = 149.80$, $p < 10^{-3}$), e.g. lower on morning shifts and higher on days off ($p < 10^{-3}$ for all comparisons).

Analyses of items relating to the workday (Table 2) showed that on shift-beginning ATCOs' alertness did not differ according to traffic load, but between shifts ($F2, 55 = 49.25$, $p < 10^{-3}$), with significant higher alertness while starting afternoon and night shifts than morning shifts ($p < .10^{-3}$). On shift-end, however, their self-rated alertness was higher when the traffic load was decreased ($F1,55 = 24.78$, $p < 10^{-3}$) and variations between shifts ($F1,55 = 62.50$, $p <$ 10-3, quadratic trend) resulted from decreased alertness at the end of both morning and night shifts compared to afternoon shifts ($p < .10^{-3}$). Likewise, moments of fatigue on duty occurred less frequently with decreased aircraft traffic ($F1,55=22.99$, $p < 10^{-3}$) and according to the shift worked ($F1,55 = 3.96$, $p < .05$), with fewer moments of fatigue on afternoon shifts compared to morning and night shifts (both comparisons $p <10^{-3}$), but also on night shifts when compared to morning shifts ($p = .051$). Further an important effect of traffic load occurred on perceived strain and workload. Indeed, when traffic load was enhanced, perceived tension was also enhanced both on shift beginning ($F1,55 = 7.38$, $p < .009$) and on shift end ($F1,55 = 11.07$, $p < .002$), and so was the perceived workload ($F1,55=72.99$, $p < 10^{-3}$). At the same time, all three items varied according to the shift considered, and both factors interacted as the beneficial effect of reduced traffic load was not apparent on the night shifts. Comparison of workload across the entire periods (Table 3) confirmed that reduced traffic resulted in reduced subjective workload ($t1,55 = 11.86$, $p < 10^{-3}$).

Quality of family life and the atmosphere in private life were not influenced by traffic intensity, but by shift (quality, $F1,55=120.56$, $p < 10^{-3}$; atmosphere, $F1,55=55.74$, $p < 10^{-3}$). Both measures were lowest when ATCOs worked morning shifts, intermediary and equivalent when they worked afternoon or night shifts and highest on rest days (for all comparisons, $p < 10^{-3}$, except for atmosphere between morning and night shifts, $p < .022$). Overall assessments of work life (Table 3) indicates that quality of work life ($t1,55 = 8.18$, $p < 10^{-3}$) and the atmosphere between team members ($t1,55 = 5.50$, $p < 10^{-3}$) were improved with reduced airplane traffic. In this case, ATCOs also rated the working hours ($t1,55 = 6.29$, $p < 10^{-3}$) and recuperative breaks as being ($t1,55 = 6.40$, $p < 10^{-3}$) more satisfactory..

Discussion

The study revealed that both aircraft traffic load and working schedule markedly interfere with ATCOs' sleep, alertness and quality of life at work, while quality of family life appeared to be less affected by these factors.

In agreement with our hypotheses, several dimensions investigated in the present study were improved by both a shift schedule change and reduced traffic intensity. ATCOs rated in both situations workload to be reduced, while work life quality and the atmosphere between team-members were improved. Interestingly however, ATCOs indicated to be equally satisfied with the initial and the modified work schedule. This may then explain why the modified work organization had altogether a rather limited impact when compared to traffic intensity (see below). Alternatively, the absence of a more appreciable effect of the new shift organization may be explained by the fact that the organizational changes were rather marginal when compared to changes described in the literature (Palay et al., 1998; Rosa et al., 1985). Further, it may not be excluded that part of the ATCOs who volunteered to participate in the study were not convinced of the usefulness of these changes and when asked directly they reported the same level of satisfaction than with the initial work organization.

The effects of traffic load and work schedule differed indeed in several respects. When traffic intensity was reduced ATCOs reported more satisfaction with sleep duration, higher alertness upon awakening and on shift-end, and fewer moments of fatigue and less tension and workload while they were on duty. These date are in agreement with previous findings demonstrating workload effects on fatigue (Akerstedt et al., 2004; Bültmann et al., 2002; Mélan et al, 2007) and extent these findings to additional dimensions. The beneficial effect of reduced traffic on tension and workload was not reported for night shifts, as expressed by interactions between shift and traffic intensity. This result was not surprising as the traffic intensity varied almost exclusively during day-time. The result also highlights that the night shift is difficult *per se* due to chronobiological constraints, and this more especially that it lasted 10h.

In contrast, the modified work schedule did not significantly enhance either of the aforementioned dimensions. On contrary, ATCOs indicated higher alertness on shift beginning with the initial work organization and not as expected with the new work organization, and also more sleep prior morning shifts and rest days. These results indicate that the shift schedule changes has a negative effect on alertness despite partially increased sleep length. These findings may be related to the position of the additional shift in the work cycle and the consequences on work. Introducing the experimental shift in the middle of the work cycle, decreased the number of rest days from three to two days in the middle of the cycle, e.g. after having worked three shifts. Further, after the 2-day pause ATCOs worked four shifts successively without a rest day. In addition, on the first two of these shifts they started work early (06:30 and 07:00 respectively for the experimental and morning shift) and on the last two shifts they ended work late (at or after 23:00 for the evening shift and 06:00 for the night shift). Taken together, the particularities of the second half of the work cycle would enhance the well documented negative effects of early starting morning shifts and of the difficulties associated with night work (Ackerstedt et al., 2004; Monk et al., 1996; Tucker et al, 1998).

The study further showed, as expected, that the shift worked also interfered with sleep, alertness and quality of life. First, the number of hours asleep markedly varied as sleep duration was significantly reduced prior morning shifts. Subjective evaluations of sleep quality and duration confirmed this effect previously described in the larger shift-work literature (Tucker et al.,, 1998). Further, ATCOs slept longest prior night shifts, thereby confirming the prophylactic value of sleep prior to this type of shift. Second, ATCOs alertness was systematically lower on days they worked morning shifts, whether they rated alertness upon awakening, on shift beginning or on shift end. Taken together, these findings stress again the deleterious effects on sleep and, as a consequence, on daytime alertness when starting work on early morning hours. Interestingly, similar results were obtained for quality of non-work life that was also significantly reduced when ATCOs worked morning shifts. The latter observation favours the idea that the quality of family life would be predominantly influenced by the shift worked rather than by other characteristics of air traffic control, including traffic intensity and shift schedule. This interpretation is further supported by the finding that the aforementioned effects of shift occurred independently of whether workload or work organization was manipulated in the study and the absence of interactions between these factors with the factor of shift.

The limitations of the study concern in particular the test material used, as the questionnaires were homemade to enable focussing on the dimensions of interest whilst limiting the time required to complete the survey. However, simply relying on subjective satisfaction ratings may be an inadequate means to assess the effects of shift schedules and traffic load. Indeed, in situations where either work or sleep hours, or both are irregular, survey questionnaires ask participants to make an average judgment, for instance a "best case scenario" for sleep length. We also agree however with Loura (2014) that direct task performance, and even more self-reported measures, may not always convey the cognitive task demands (planning, decision making, monitoring) and factors (skills, training, experience, fatigue, various stressors) known to mediate the relationship between task demands and the workload experienced by a controller (Nealley & Gawron, 2015).

Conclusions

Based on the results of this study, the measures to keep the controller’s workload at a manageable level can be explored, as has been proposed elsewhere (Vetter et al., 2015). To prevent aircraft accidents and cope with the projected increase of traffic demand in the future, the study of human factors in ATC must continue. A prospective investigation of sleep, alertness, tension and workload would usefully complete the findings of the retrospective investigation of these dimensions.

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