Accelerating the future of aerospace

2nd Effectiveness Study of Flight Time Limitations (FTL 2.0)

EASA Fatigue Risk Management Conference Madrid | 4/5 Feb 2025

JEPPESEN

DLR

Stockholm University

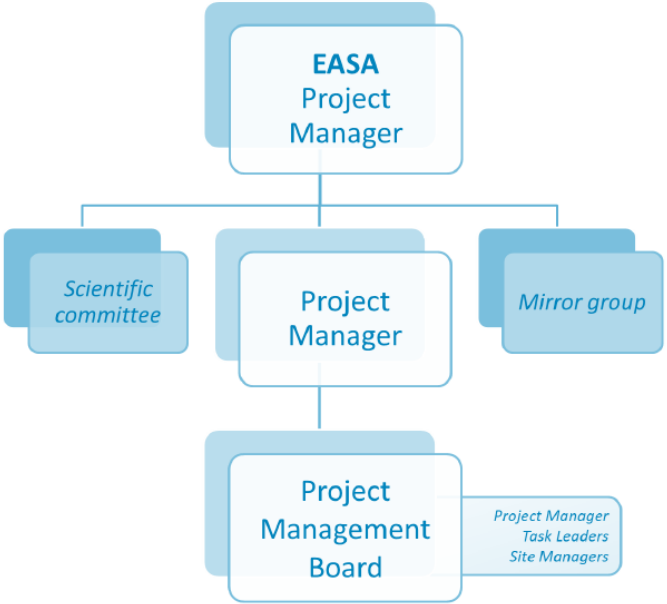
Finnish Institute of Occupational Health

Objectives FTL 2.0

- Review the effectiveness of the flight and duty time limitations and rest requirements
  - In addition to the work performed during previous contract (FTL1).

- An assessment of the impact on aircrew alertness of:
  - The following aircrew duty periods
    1. Duties of more than 13 hours at the most favourable time of the day;
    2. Duties of >11 hours for crew members in an unknown state of acclimatisation;
    3. Duties including a high level of sectors (>6);
    4. On-call duties: other than airport standby - followed by flight duties.
  - Controlled Rest: including an analysis of the conditions and circumstances under which CR is used

Parties involved



Consortium
- Netherlands Aerospace Centre (NLR) – consortium lead
  - Alwin van Drongelen (PM)
- Stockholm University – consortium partner
  - Torbjörn Akerstedt
- Finnish Institute of Occupational Health (FIOH) – consortium partner
  - Mikael Sallinen
- German Aerospace Centre (DLR) - subcontractor
  - Daniel Aeschbach & Dorothee Fischer
- Jeppesen - subcontractor
  - Tomas Klemets

EASA
- Project Manager: Emmanuel Isambert
- Technical Lead: Irina Petrova

Scientific Committee
- Alex Holmes, Barbara Stone, Kristjof Tritschler

Mirror Group
- representatives from member states, regulators, airlines and aircrew associations

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FTL 2.0 timeline

	Phase 1	Phase 2	Phase 3
	December 2021 - January 2023 **Induction, roster selection & controlled rest characterisation**	**March 2022 - December 2024** **Data gathering and analysis**	**February 2025 - May 2025** **Data merging and elaboration of final recommendations.**
Activities	Task 1.1 - baseline	Task 2.1 - define scope	task 2.5 - merge results
	Task 1.2 - target aircrew	Task 2.2 - data collection	task 2.6 - suitability fatigue mitigation
		Task 2.3 - analyses	task 2.7 - conclusions/recommendations
		Task 2.4 - safety metrics	

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Today (10:15-11:30)

- Six presentations
- 10-15 minutes per FDP of interest
  - Few questions in between
  - Longer discussion after last presentation

- D2.2 (data collection campaign)
- D2.3 (results per FPD of interest).
  1. FDP1 (>13h duties) – Mikael Sallinen
  2. FDP3 (X-state duties) – Dorothee Fischer
  3. FDP4 (>6 sector duties) – Torbjorn Akerstedt
  4. FDP5 (other than airport standby) – M.S.
  5. Controlled Rest – Laurie Marsman

- No recommendations for the regulations yet

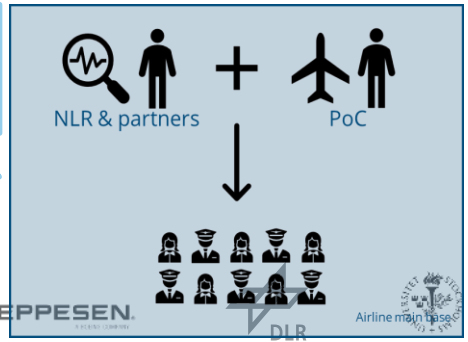
Task 2.2

FTL 2.0 Data Collection Campaign

Methods

- Eligible airlines selected based on
  - Size, geographical region, transport type
  - Actual flown schedules & willingness to participate
- Aim for high quality data and within subject analysis
  - Tailored procedure per airline
  - Dedicated measurement equipment
  - Data collection over consecutive duty days, for multiple weeks
  - Real-time data monitoring and personal contact

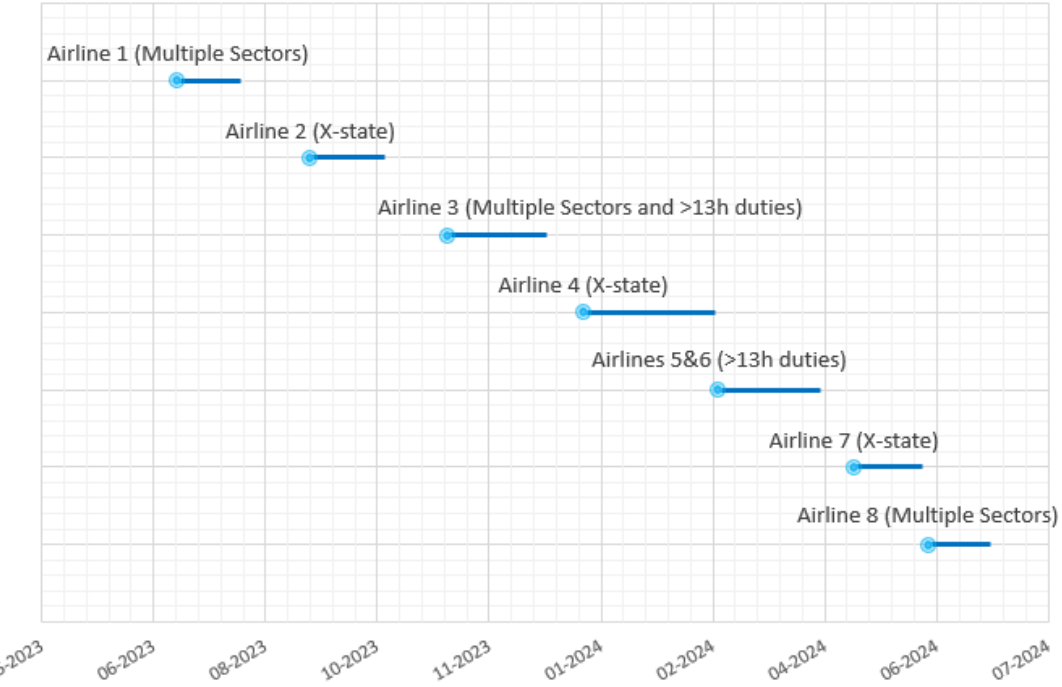
Max 60 participants per airline



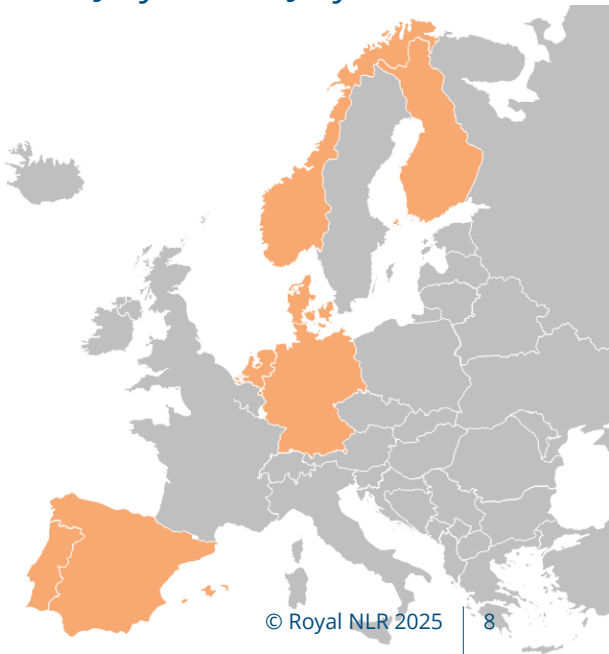
Phone + actiwatch

2 to 4 weeks of data collection

Timeline data collection campaign



- 36 airlines approached
  - 19 willing to participate
  - 8 selected based on schedules
- Measurements July 2023 – July 2024



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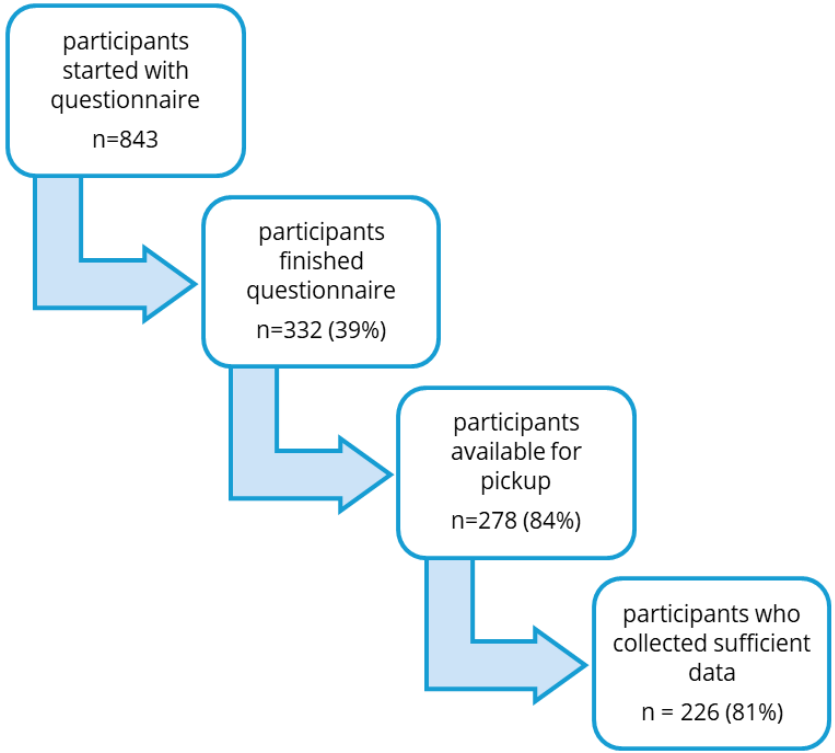
Participants

- 226 participants with good quality data
  - 56% male
  - 55% cabin crew
  - 86% full-time
  - 96% in good health
  - High average work ability (8.3 out of 10)
  - Workload past month
    - the same as ‘normal’ (41%)
    - somewhat lower (19%)
    - somewhat higher (24%)
- 3.525 duty days with questionnaire data
  - Fatigue (KSS and SP)
  - Performance (PVT), sleep, workload
  - Flight and duty characteristics



Questions

Task 2.3

Analysis of the findings from the data collection

FDPs of more than 13 hours at the most favourable time of the day (FDP1)

Mikael Sallinen

Aims and hypotheses

- The main aims were to
  - compare the level of fatigue between FDPs > 13 h and FDPs ≤ 13 h flown at the most favourable time of the day
  - identify the main predictors of on-duty fatigue during these FDPs.

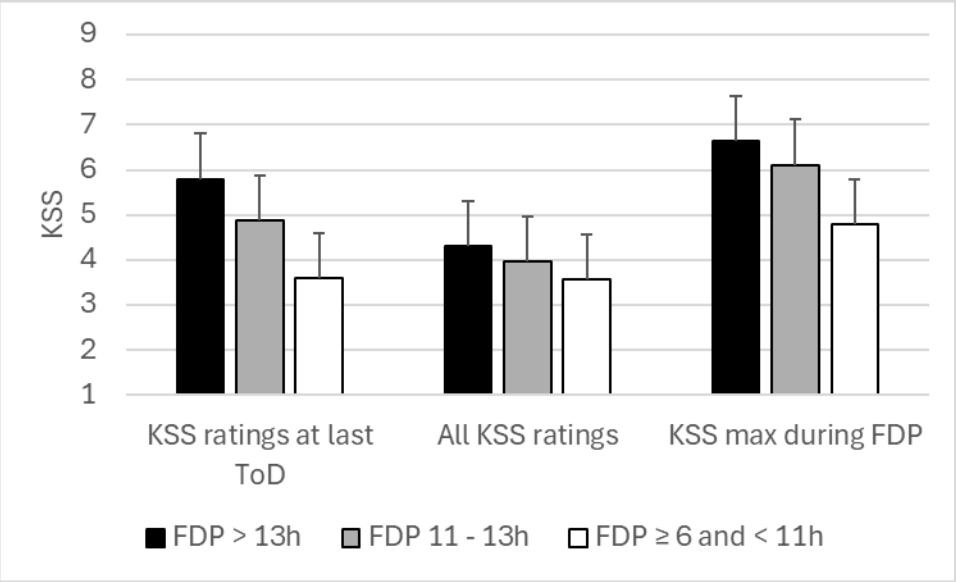
- The hypotheses were that
  - fatigue is higher during FDPs > 13 h than during FDPs ≤ 13 h.
  - FDP duration is a significant predictor of on-duty fatigue.

Results

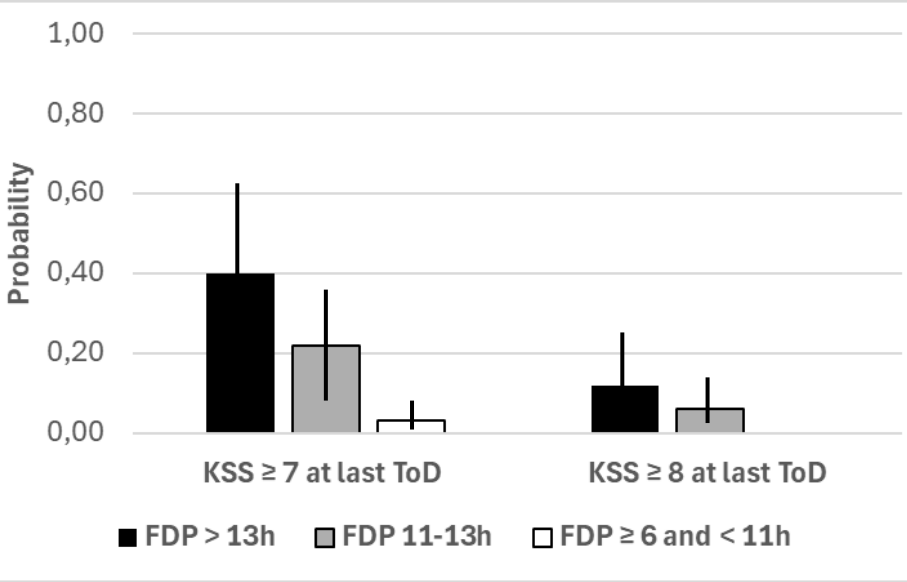
Table 1. Descriptives of participants and FDPs. All FDPs start 06:00h - 13:29h, include 1-2 non-augmented flights, and are flown in a known state of acclimatisation.

Variable	FDP > 13h	FDP 11 - 13h	FDP ≥ 6 and < 11h
Number of FDPs	**33**	**46**	**133**
Number of participants (pilots / cabin crew)	29 (12/17)	41 (24/17)	82 (38/44)
Age (years)	40 ± 8	42 ± 9	40 ± 9
Gender (m/f) (%)	45/55	43/57	42/58
Main sleep + naps (hours)	**7.45 ± 1.65**	**7.54 ±1.63**	**6.94 ± 1.54**
FDP start time (h:min)	10:16 ± 1:37	10:51 ± 2:03	8:45 ± 2:24
FDP end time (h:min)	23:48 ± 1:38	22:46 ± 2:49	17:10 ± 2:59
FDP duration (h:min)	**13:31 ± 0:17**	**12:07 ± 0:35**	**8:25 ± 1:19**
WOCL encroachment (%)	**9.1**	0	0
FDP type (Early start/Late finish/Night/Non-disruptive) (%)	**0/67/9/24**	**0/54/0/46**	**20/2/0/78**

Results – KSS* at last ToD



Mean (± SD) KSS ratings during FDPs > 13h and control FDPs (11-13h and 6 - < 11h).



Probability (95% CI) of high fatigue (KSS ≥ 7) at last ToD during FDPs > 13h and control FDPs (11-13h and 6 - < 11h).

***Karolinska Sleepiness Scale**

1 - Extremely alert , 2 - Very alert, 3 - Alert, 4 - Rather alert, 5 - Neither alert nor sleepy, 6 - Some signs of sleepiness,

7 - Sleepy, but no effort to keep awake, 8 - Sleepy, some effort to keep awake, 9 Very sleepy, great effort to keep awake

Main results of regression analyses

Main predictors[1] of KSS level

FDP duration*
- *fatigue level higher for FDPs >13h and 11-13h than FDPs 6 - <11h*

Number of sectors*
- *fatigue level higher for 2-sector FDPs than single sector FDPs*

Time awake*
- *the longer the time awake, the higher the level of fatigue*

**significant in single and multivariable analysis*

Main predictors[1] of KSS ≥ 7

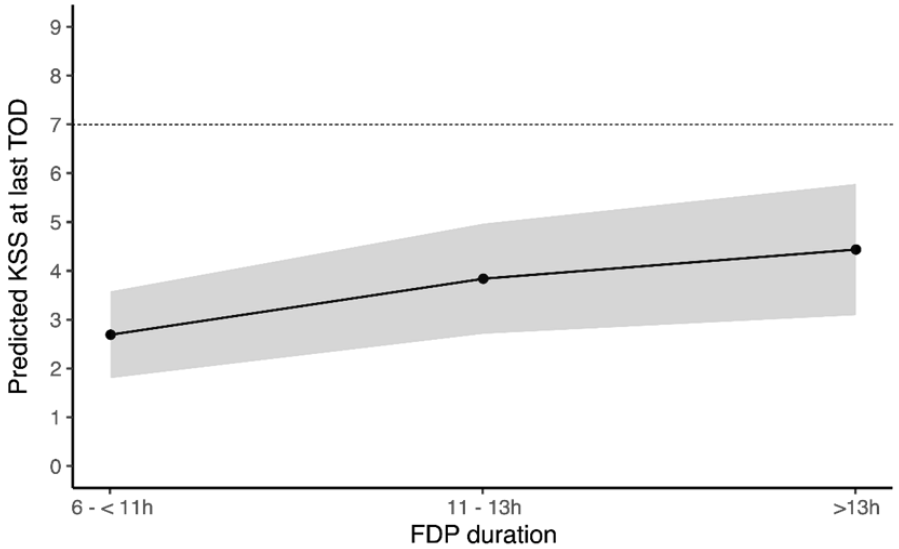
FDP duration**
- *fatigue level higher for FDPs >13h and 11-13h than FDPs 6 - <11h*

Time awake**
- *the longer the time awake, the higher the level of fatigue*

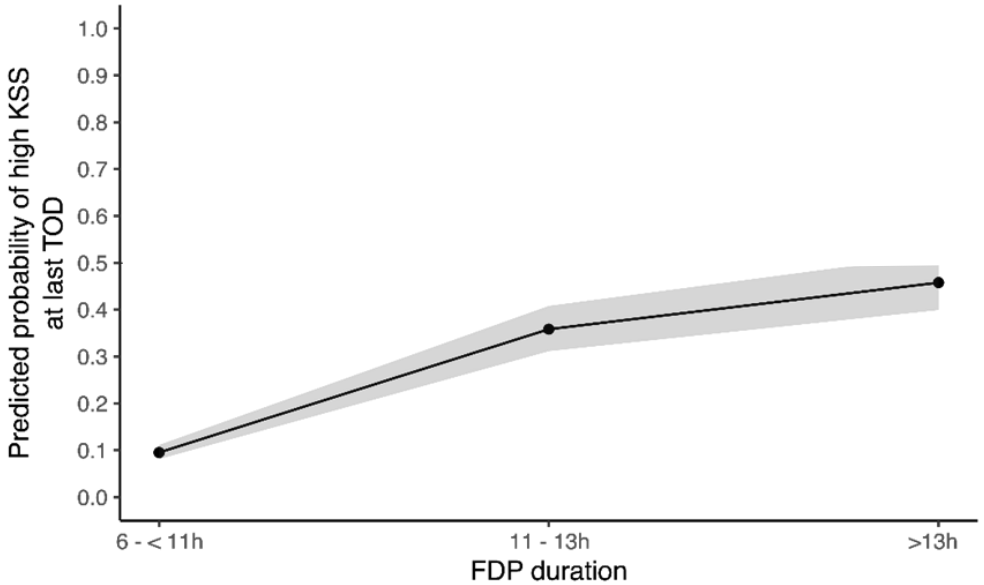
***significant only in single variable analysis*

[1]Predictors: age, crew category, gender, # of sectors, FDP duration, time of day, time awake, prior sleep

Results: predicted fatigue



Predicted KSS values (mean, SE) at last ToD by FDP duration based on the multivariable analysis. 148 FDPs, 86 subjects.



Predicted probability of high fatigue (KSS ≥ 7) at last ToD by FDP duration based on the multivariable analysis. 148 FDPs, 86 subjects.

Conclusions

- FPD duration is a significant fatigue factor during FDPs “flown at the most favourable time of the day”.
- Fatigue (at last sector’s ToD) is at a higher level during FDPs > 13h and FDPs 11h – 13h than FDPs 6h -11h.
- FDPs > 13h and FDPs 11h – 13h did not statistically differ from one another in the present study, which may be due to insufficient data on FDPs > 13h.
- The results show that long FDPs “flown at the most favourable time of the day” are often disruptive schedules:
  - 67% of FDPs > 13h fell into the category of late finish FDP.
  - 9% of the FDPs > 13h were night FDPs .
  - Only 24% of FDPs > 13h were non-disruptive schedules (day FDPs).
  - 80 % of FDPs < 11h were day FDPs.

Questions

FDPs of more than 11 hours in an unknown state of acclimatization (FDP3)

Dorothee Fischer

States of acclimatisation

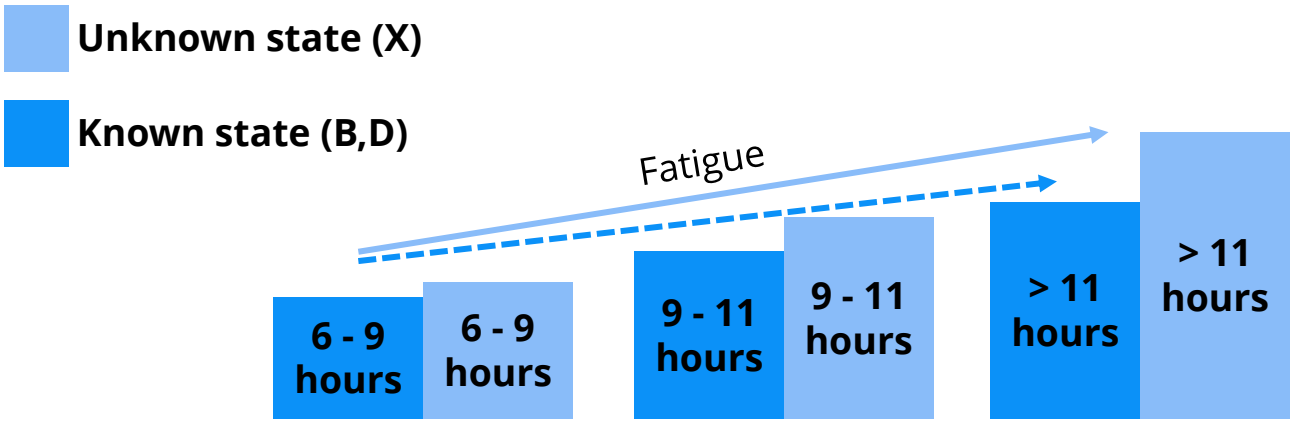
Definitions of acclimatisation states according to EASA ORO.FTL.105.

Time difference (h) between reference time and local time where the crew member starts the next duty	Time elapsed since reporting at reference time				
	< 48h	48 – 71:59	72 – 95:59	96 – 119:59	≥120
< 4	B	D	D	D	D
≥4 and ≤6	B	X	D	D	D
>6 and ≤9	B	X	X	D	D
>9 and ≤12	B	X	X	X	D

Known state (B,D)

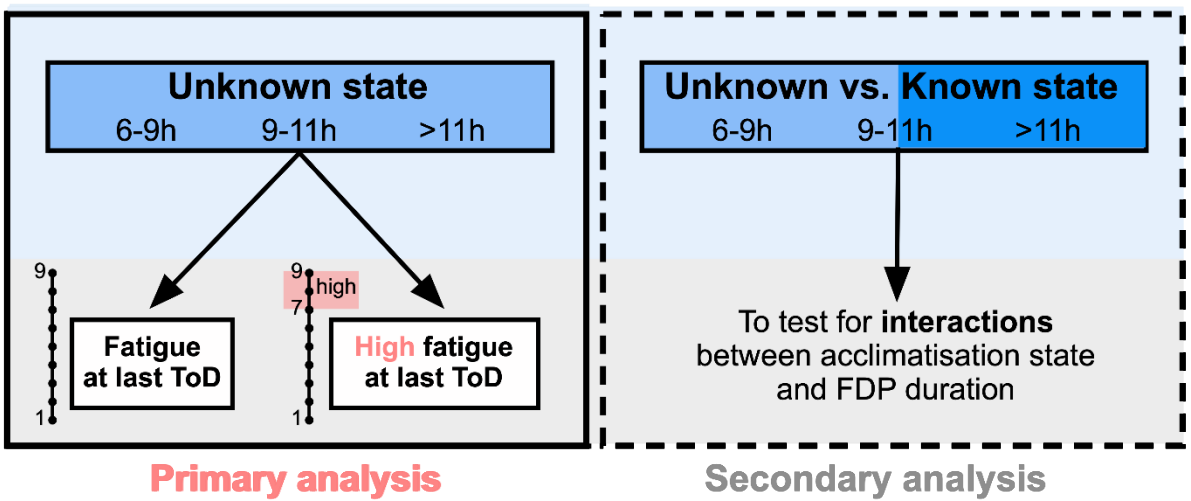
Unknown state (X)

Aims and hypotheses regarding FDPs > 11h flown in unknown state of acclimatisation



- Fatigue increases with longer FDP duration.
- Fatigue is higher when in an unknown state of acclimatisation.
- The increase in fatigue is steeper for unknown-state FDPs (“interaction effect”).

Sample and analyses



n = 21 participants, 21 FDPs1

n = 133 participants, 376 FDPs[1]

[1]max. 3 sectors, min. 6-h duration, non-augmented.

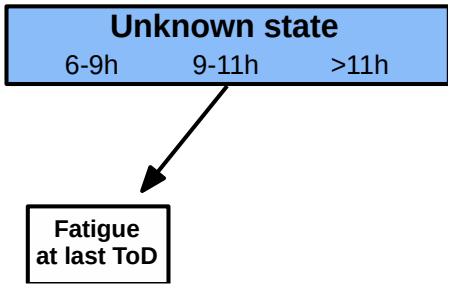
Description of unknown-state FDPs

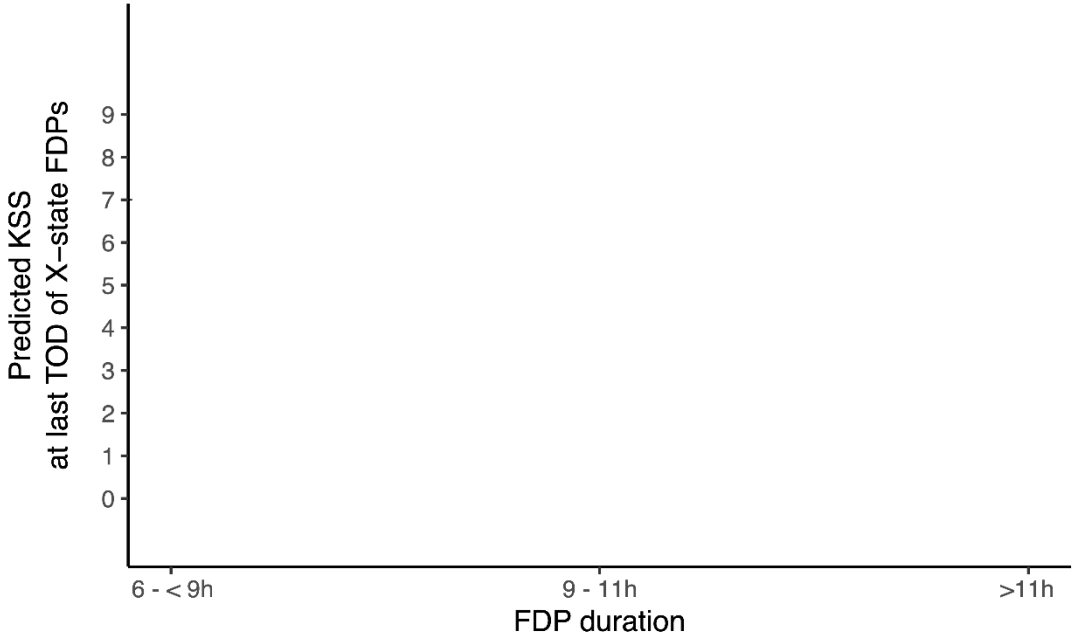
Available X-state combinations between time zones crossed and time elapsed since reporting (N = 21 participants, 1 FDP per participant).

Time difference (h) between reference time and local time where the crew member starts the next duty	Time elapsed since reporting at reference time				
	< 48h	48 – 71:59	72 – 95:59	96 – 119:59	≥120
< 4	B	D	D	D	D
≥4 and ≤6	B	18[1]	D	D	D
>6 and ≤9	B	2[1]	1[1]	D	D
>9 and ≤12	B	--	--	--	D

[1]*Of these 21 X-state FDPs, 14 (67%) were nighttime FDPs.*

Does fatigue increase with longer durations of unknown-state FDPs?

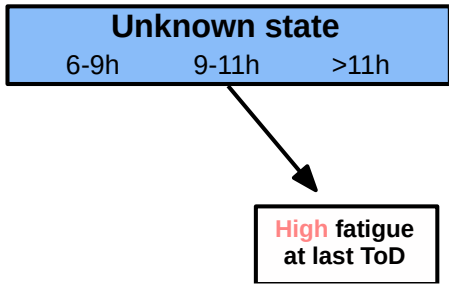


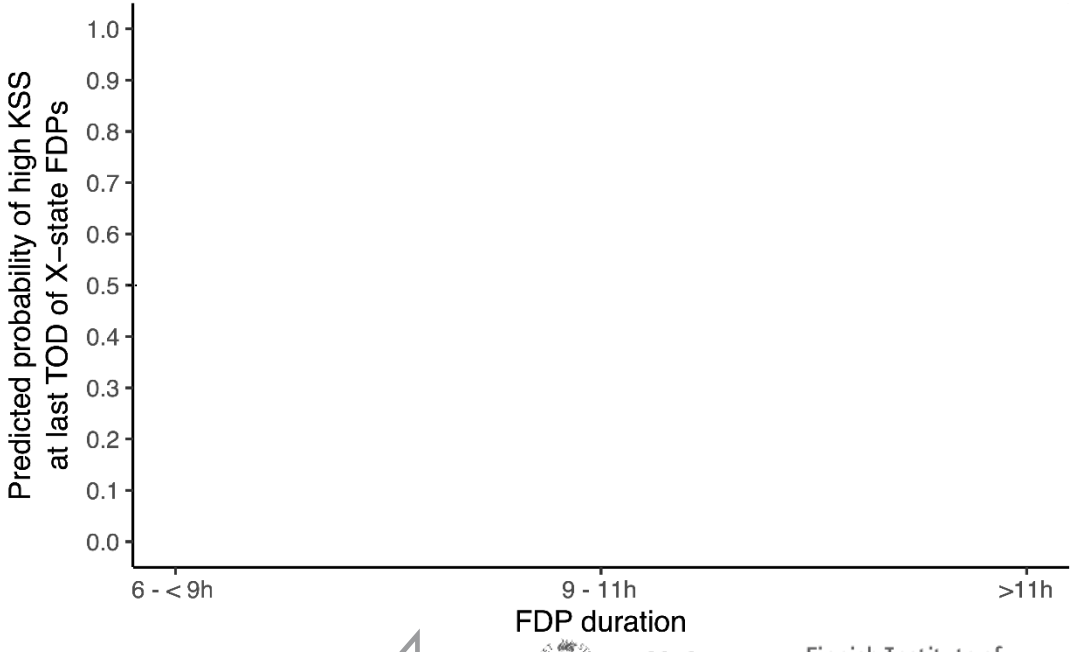


Fatigue is significantly increased for unknown-state FDPs of 9 hours or longer.

Adjusted for age, gender, crew category, sectors, time awake, time of day, 24-h sleep duration, flight direction, timezones crossed, and layover length

Does the occurrence of **high** fatigue also increase with longer durations of unknown-state FDPs?

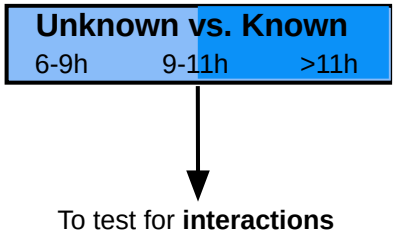




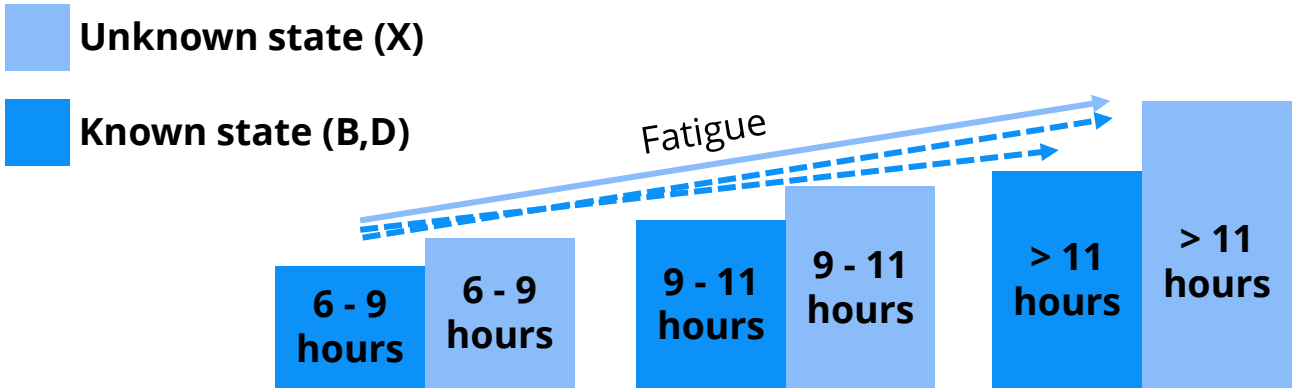
The probability of high fatigue is increased for unknown-state FDPs of 9 hours or longer.

Adjusted for age, gender, crew category, sectors, time awake, time of day, 24-h sleep duration, flight direction, timezones crossed, and layover length

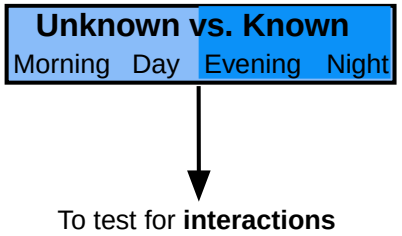
Does an unknown state exacerbate fatigue of **long** FDPs?



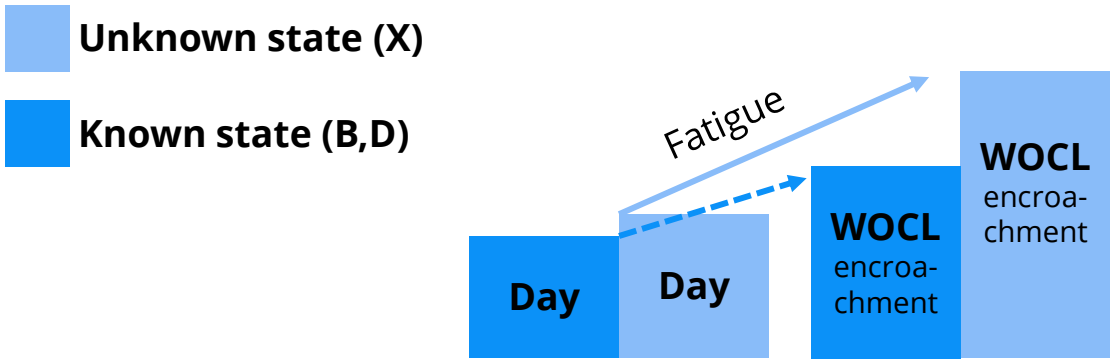
- Acclimatisation state did not interact with **FDP duration**.
- An unknown state increased the likelihood of high fatigue at last ToD.



Does an unknown state exacerbate fatigue of **night** FDPs?



- Acclimatisation state did interact with **FDP timing**:
  - nighttime (during WOCL) and early-morning (start 2:00-6:59) FDPs appeared to exacerbate the effects of flying in an unknown-state on fatigue.



Conclusions

Unknown state
6-9h 9-11h >11h

- **For non-augmented crews operating during the nighttime in an unknown state of acclimatisation, fatigue was significantly increased for FDP durations of 9 hours or more.**
- Effects of ‘X-state’ vs. ‘nighttime’ could not be fully separated, since daytime X-state FDPs were limited.

Unknown vs. Known state
WOCL encroachment

- Analyses suggest that an unknown state of acclimatisation increases fatigue; and that
- fatigue at last ToD is exacerbated by the combination of an unknown state and WOCL encroachment.

Questions

FDPs with a high level of sectors (> 6) (FDP4)

Torbjörn Akerstedt

Approach

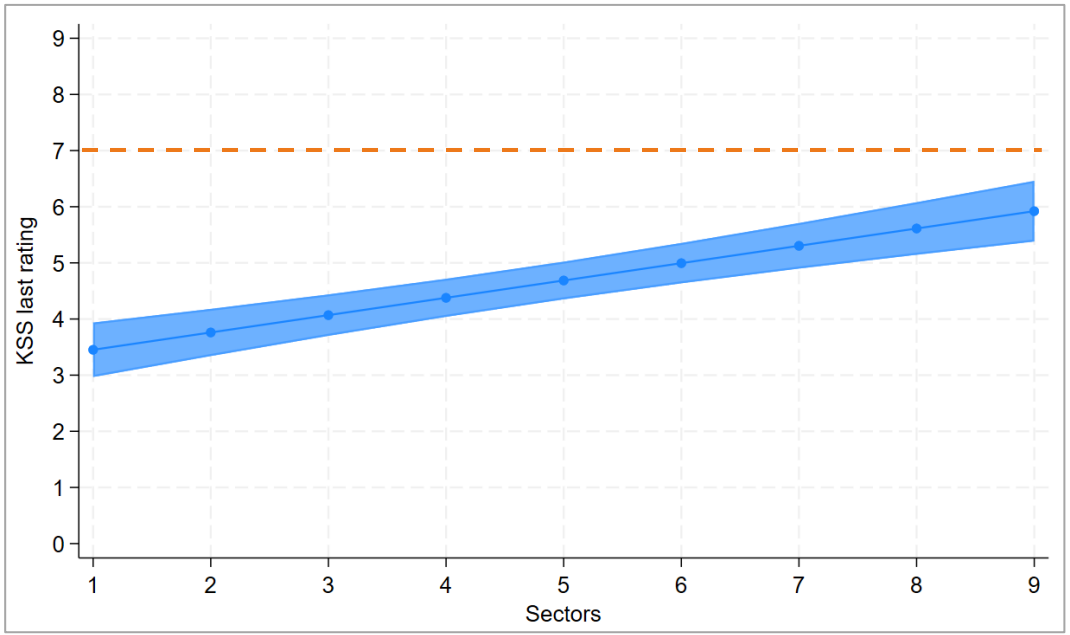
- Main questions
  - Does fatigue increase gradually with increasing number of sectors.
  - Is flying >6 sectors during an FDP associated with more fatigue than fewer sectors
  - To what extent are high fatigue levels reached at high levels of sectors
- N= 77, observations/participant = 4.7
- Mixed model regression vs fatigue outcomes

Variables that predict fatigue (simultaneously)

- Sectors (1-9) (increases fatigue)
- FDP duration (increases fatigue)
- Sleep (reduces fatigue)

- Age, gender , crew category, time awake, time of day (no nights) do not affect fatigue

Predicting KSS (at last sector) from sectors



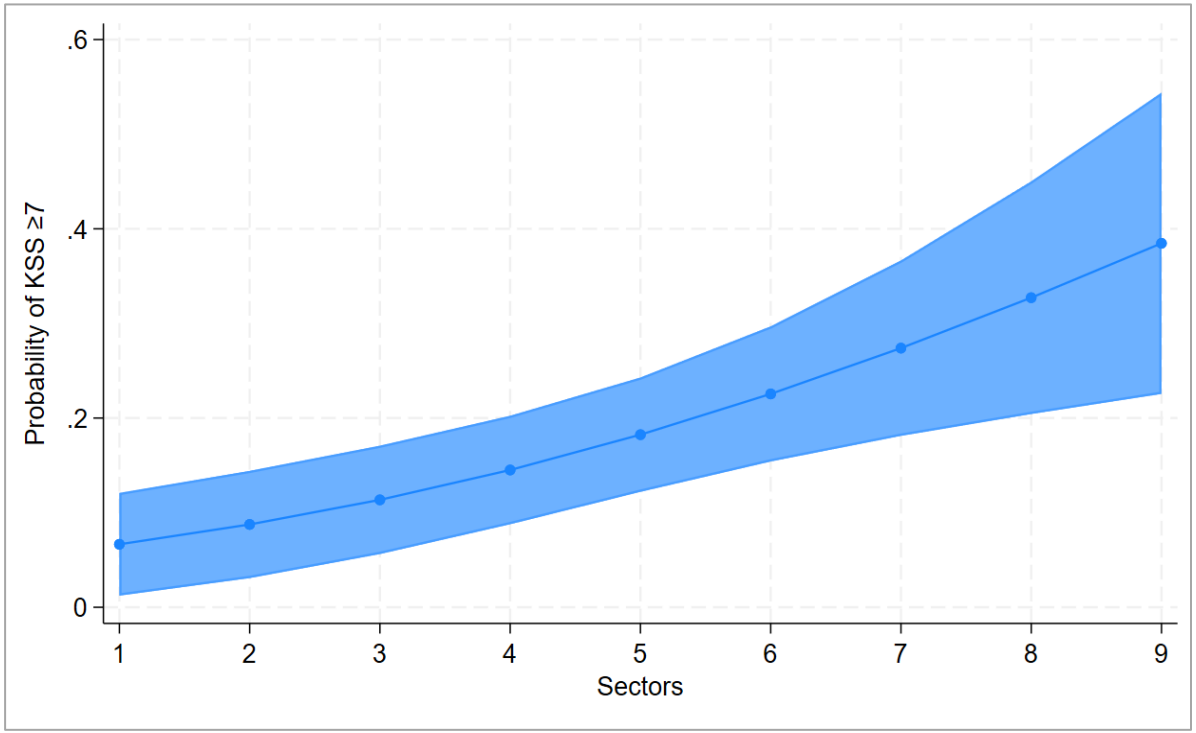
Mean
95%CI

Adjusted for all other variables

KSS as a function of Sectors and FDP duration

	Number of Sectors						
FDP hours ↓	**1**	**2**	**3**	**4**	**5**	**6**	**7**
13	4.9±.5	5.1±.4	5.2±.3	5.3±.3	5.5±.2	5.6±.2	5.8±.2
12	4.8±.4	4.9±.4	5.0±.3	5.2±.2	5.3±.2	5.5±.2	5.6±.2
11	4.6±.4	4.7±.3	4.9±.3	5.0±.2	5.1±.2	5.3±.2	5.4±.2
10	4.4±.3	4.6±.3	4.7±.2	4.9±.2	5.0±.1	5.1±.1	5.3±.2
9	4.3±.3	4.4±.2	4.5±.2	4.7±.2	4.8±.1	4.9±.1	5.1±.2
8	4.1±.3	4.2±.2	4.4±.2	4.5±.1	4.6±.1	4.8±.1	4.9±.2
7	3.9±.2	4.1±.2	4.2±.1	4.3±.1	4.5±.1	4.6±.2	4.8±.2

Predicting high fatigue (KSS≥7), multivariable analysis



24h sleep is the only significant other predictor

For KSS≥8 only sleep duration became a significant (neg) predictor

A note on predicting SP

- SP is not predicted by sectors, but by FDP duration
  - multivariable model
- But sectors is still a significant predictor in the single variable analysis
- The association between KSS and SP is very strong

Conclusion

- Fatigue (KSS) increases with number of sectors, and particularly at the transition into ≥6 sectors
- FDP duration also increases fatigue independently from sectors
- The considerable importance of sleep duration for fatigue should be considered

Questions

Some basic data mean±SD or %

	FDPs with 1-6 Sectors	FDPs with >6 Sectors
Observations	284	94
KSS at last rating	4.3±2.0	4.9±2.0
KSS≥7 at last rating	14.4%	26.8%
Age	41.3±9.0	43.9±9.4
Gender (male) N/%	31.3%	68.1%
Crew category Cockpit N/%	34.9%	75.5%

Predicting KSS at last sector

When instead>6 vs ≤6 are inserted, the result becomes 0.57±.22*

Appr same result if all data (incl long-haul) are used

Predictor	KSS single variable Coeff±se/Constant	KSS multivariable Coeff±se
Age	-0.01±.02/5.0	-0.02±.01
Cabin (Cockpit ref)	-0.13±.36/4.6	-0.07±.44
Male (fem ref)	0.17±.36/4.4	0.14±.43
Sectors (1-9)	**0.31±.05*****/3.1	**0.16±.07***
FDP duration	**0.23±.03*****/2.8	**0.16±.06****
Timeawake	**0.11±.03*****/3.3	0.01±.05
Morning, ref Day Evening	 **-0.78±.22***** -0.04±.24/4.8	 -0.01±.23 0.39±.34
24hSleep	**-0.27±.06*****/6.4	**-0.27±.06*****
Constant (multiv)		5.30

Other than airport standby FDPs (FDP5)

Mikael Sallinen

Aim and research questions

Aim

- to examine the 18-h awake time rule[1]

What is the association of awake time with fatigue during FDPs assigned during other standby periods?

- What is the association of *prior sleep* with fatigue during FDPs assigned during other standby periods?
- What is the association of *sleep-to-awake time ratio* with fatigue during FDPs assigned during other standby periods?
- Do fatigue levels differ between FDPs assigned during other standby periods and FDPs scheduled in duty rosters?

[1] *combination of standby and an assigned FDP should not lead to an awake time longer than 18 hours*

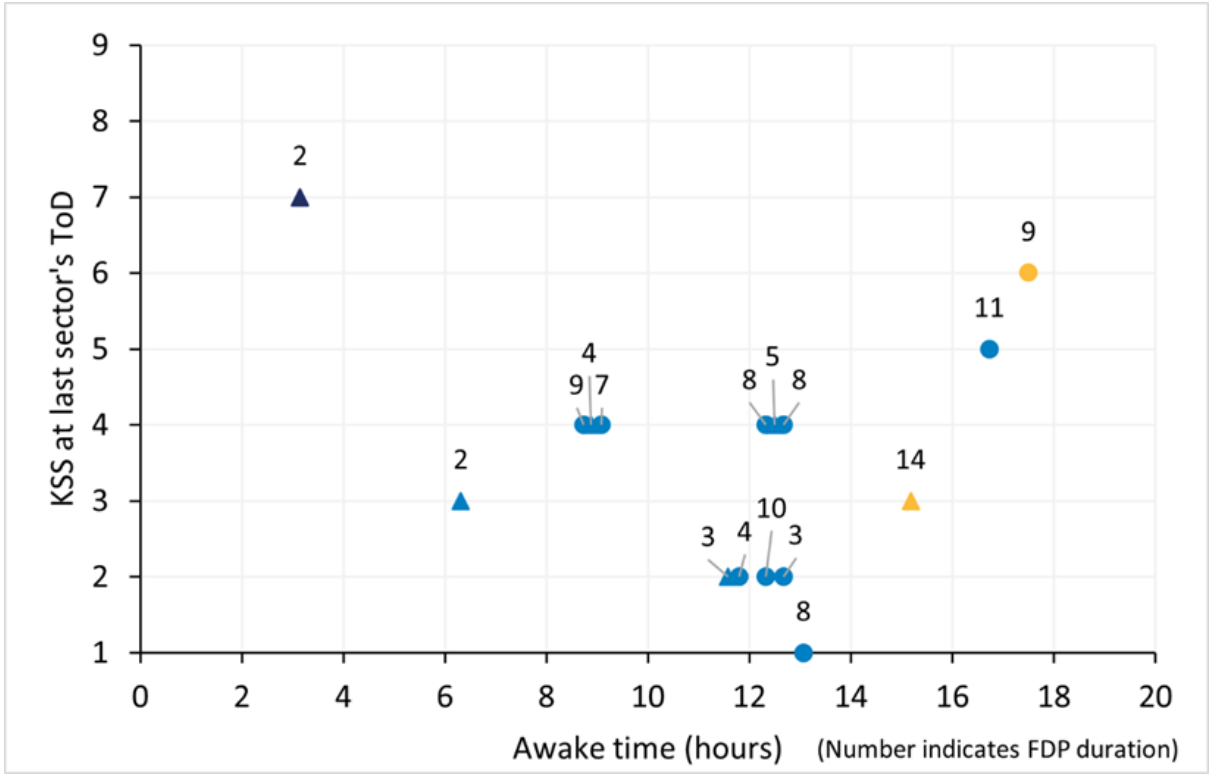
Results (1)

Table 1. Descriptives of participants and FDPs assigned during other standbys.

Variable	Assigned FDPs
Number of FDPs	**27**
Number of FDPs measured from pilots /cabin crew	17/10
Number of pilots / cabin crew	13/8
Age (years)	42.0 ± 9.6
Gender (m/f) (%)	48/52
Commuting time (min)	49.0 ± 43.5
FDP start time (h:min)	**12:24 ± 3:48**
FDP end time (h:min)	**19:13 ± 4:18**
FDP duration (h:min)	**6:49 ± 2:58**
FDP type (ES/LF/N/ND) (%)[1]	**7/11/0/82**
Number of sectors	2.2 ± 1.2
Standby hours prior to an assigned FDP	**1:53 ± 1:59**

[1]ES = Early start FDP (start time 05:00h – 05:59h (early type country) or 05:00h – 06:59h (late type country, most restrictive); LF = Late finish FDP (= end time 23:00h – 01:59h (early type country, most restrictive) or 00:00h – 01:59h (late type country)); N = Night FDP (any portion of the FDP between 02:00h – 04:59h); ND = Non-disruptive FDP (whole FDP between 06:00h – 22:59h (early type country) or FDP between 07:00h – 23:59h (late type country)).

Results (2)



early start
non-disruptive
late finish

Figure 1a. Scatter plot between **prior awake time** and KSS ratings at last ToD. N=16.

Results (3)

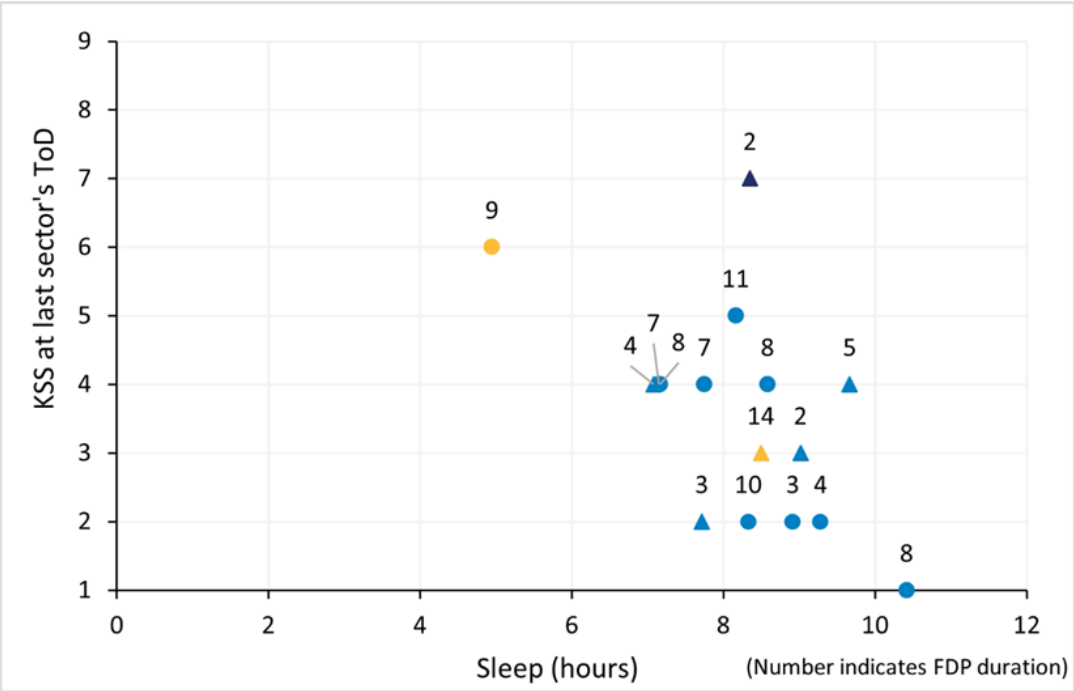


Figure 1b. Scatter plot between **prior sleep** and KSS ratings at the ToDs of the last sectors. N=16.

- unadjusted model for prior sleep: coefficient -0.782, 95% CI -0.990;-0.574, p<0.001
- adjusted model for prior sleep*: coefficient -0.685, 95% CI -1.116;-0.254, p=0.005

**age, gender, and occupation as covariates*

Results (4)

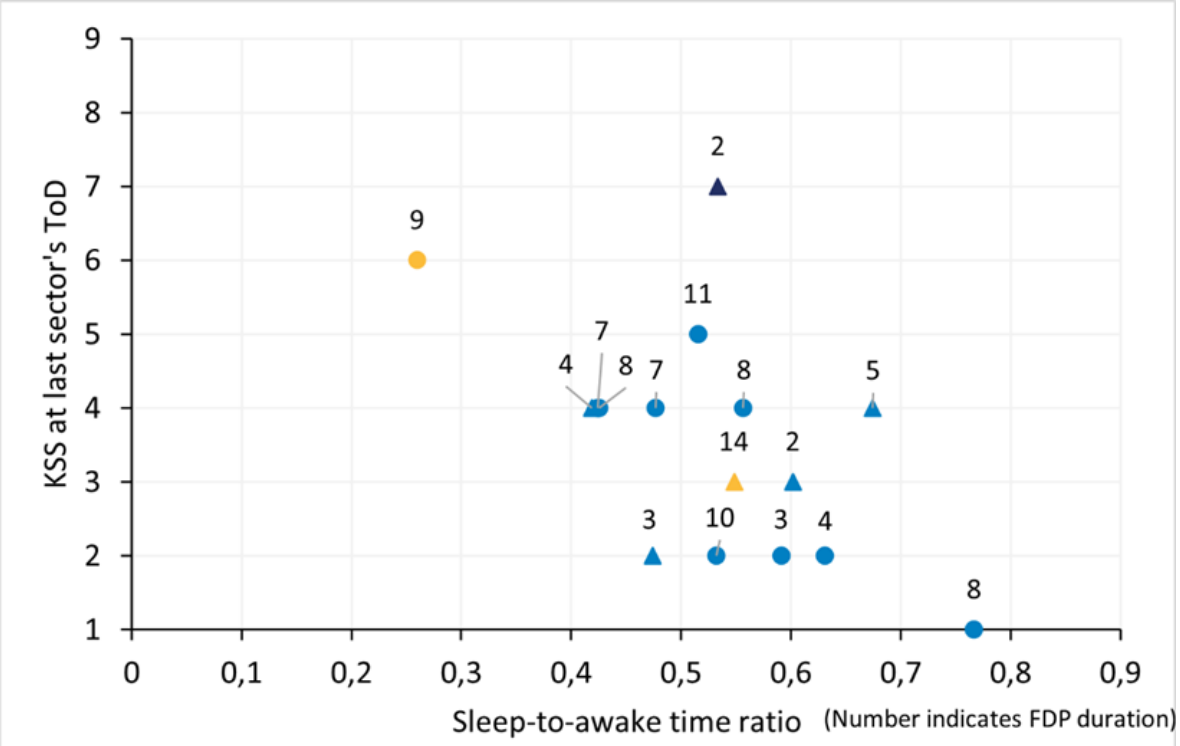


Figure 1c. Scatter plot between **sleep-to-awake ratio** and KSS ratings at the ToDs of the last sectors. N=16.

- unadjusted model for SWR: coefficient -8.446, 95% CI -10.894;-5.998, p<0.001
- adjusted model for SWR*: coefficient -6.488, 95% CI -10.483;-2.494, p=0.004

*age, gender, and occupation as covariates

Results (5)

Table 2. Comparison of KSS ratings between FDPs assigned during other standby and FDPs scheduled in duty rosters.

Outcome	N	FDPs assigned during standbys	FDPs scheduled in duty roster	Paired samples t-test
KSS at ToD of last sector	9	3.3 ± 1.2	3.3 ± 1.4	-
Mean KSS during FDP	19	3.4 ± 1.2	3.6 ± 1.0	t(18)=-1.049 p=0.308
Max KSS during FDP	19	4.6 ± 1.9	4.7 ± 1.6	t(18)=-0.129 p=0.899

Conclusions

- At least daytime FDPs assigned during other standbys do not appear to break the 18h rule.
- Self-rated fatigue during FDPs assigned during other standby seems to be associated more closely with prior sleep and prior sleep-to-awake time ratio than with prior awake time.
- Self-rated fatigue levels during these assigned FDPs do not differ from corresponding FDPs scheduled in the duty roster.
- Further research is needed to examine the effectiveness of the 18 hours awake time cap rule in the context of assignments which end late and/or during the night.

Questions

Conditions, circumstances, and reasons for Controlled Rest (CR)

Laurie Marsman

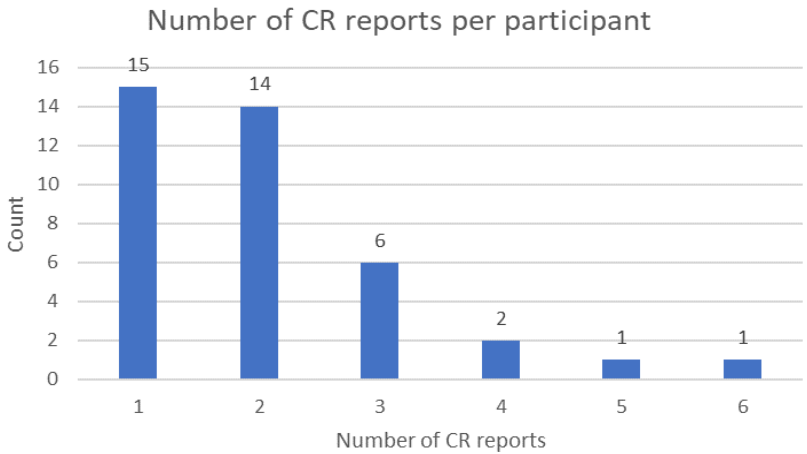
Main questions

1. What are the characteristics of flights that have a high prevalence of CR?
2. What are the conditions, circumstances, and reasons for flight crew members to use CR?
3. Is there a difference in fatigue between flights in which CR is taken and in similar flights in which it is not taken?

Participants

39 (38.2%) out of 102 pilots reported CR

- 43.05 ± 8.64 years old
- 37 (94.9%) male
- Experience 15.87 ± 8.03 years



Matching procedure

Characteristics of FDPs with CR

- **Time of day (night)**, **eastward flight direction**, the number of **time zones crossed** and being in an **X-state** were significant predictors of CR

- In the multivariable analyses, **eastward flight direction, time zones crossed and being in an X-state** remained significant

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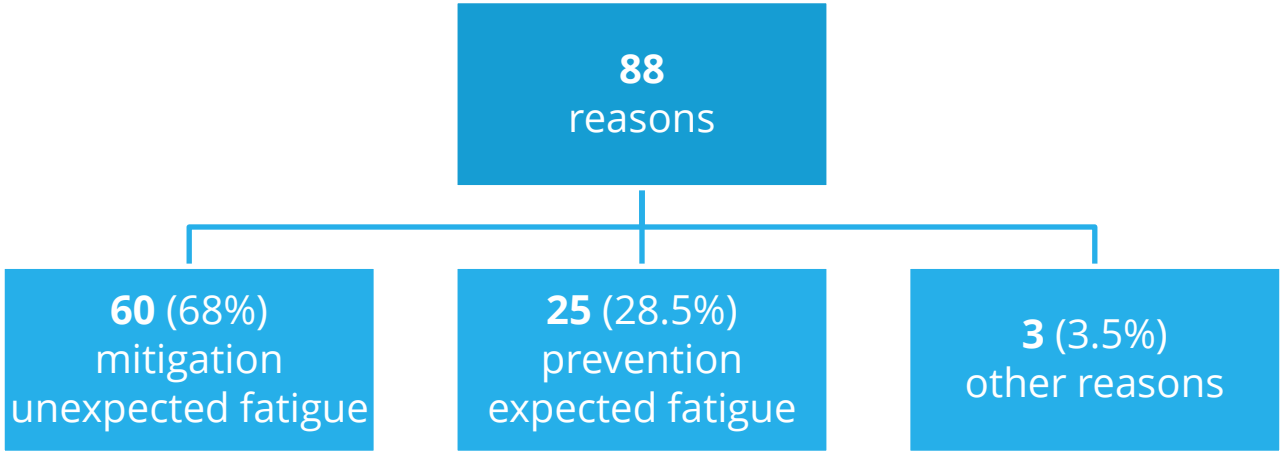
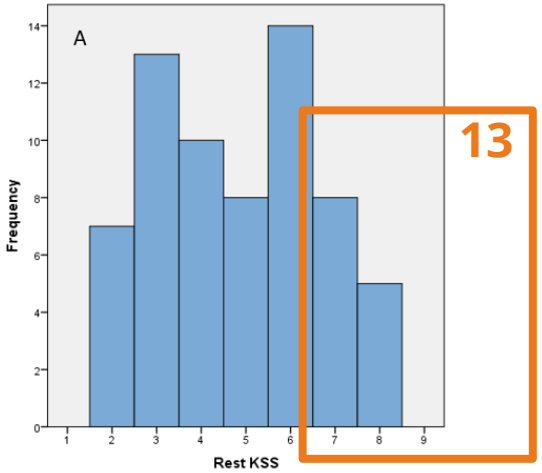
Reasons for pilots to take CR

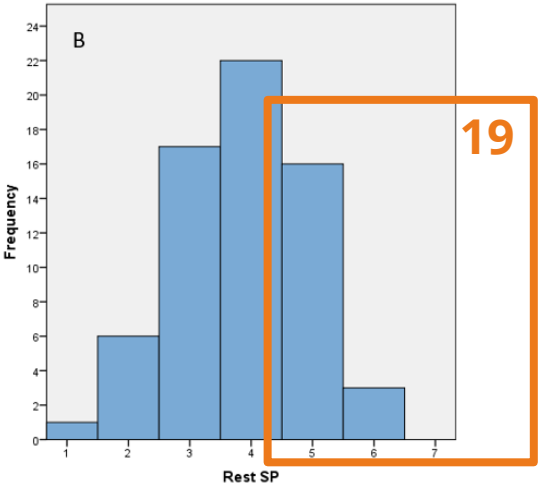


Usage of Controlled Rest

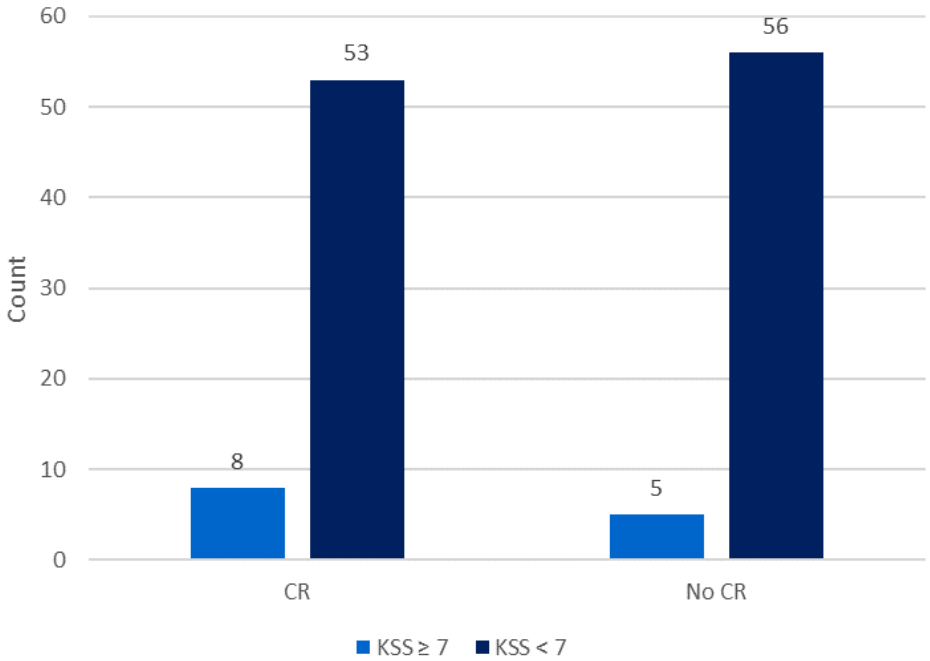
- 6 CR instances (7.5%) were longer than 45 minutes
- 20 (25%) included more than 30 minutes sleep

Variable	Outcomes
CR duration (mins)	34.51±24.2
Sleep within CR (mins)	24.15±19.2
Awake within CR (mins)	19.06±20.7
Percentage sleep within CR	51.3±33.9
Mean KSS after rest	4.82±1.8
Mean SP after rest	3.85±1.1





Comparison high fatigue in FDPs with/without CR



- **KSS ≥7 across the entire flight** (yes/no): OR = 2.6 (*p*=.004)
- **KSS ≥7 at the last ToD**, OR = 1.691 (NS)

Factors involved in high fatigue

- **Time awake** at end of FDP, **time of day (night)**, **eastward flight direction**, and being in an **X-state** are significant predictors of high fatigue at ToD

- In the multivariable analyses, only **eastward flight direction, time of day (night)**, and **CR usage** remain significant

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Conclusions

1. FDPs with **CR** are characterized by a **higher number of time zones crossed**, **eastward flight direction**, and being in an **X-state**.
2. The mean duration of CR found is ± **30 minutes,** with ± **24 minutes of sleep.** More than 1/3 of the CR observations were because of **prevention** of **expected fatigue.**
3. Higher occurrence of high fatigue in FDPs with CR in comparison to matched flights without CR
   – But NOT with high fatigue at last ToD. **Positive effect of CR?**

Questions

FTL 2.0 Work ahead

- Discussion with stakeholders
  - here & now
- Reflection & merge / drafting recommendations / overall conclusions
  - D2.5/ D2.6 / D2.7
  - May 1st 2025
- Final dissemination event with Mirror Group
  - May 28th 2025

Thank you for your attention!

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