



ATCO's Perceived Workload and Monitoring Performance between Traditional and Digital Tower Operations

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- **New Issues of HP on Digital Tower Operations**
- **Assessing Monitoring Performance and Workload**
 1. **NASA-TLX to Evaluate ATCOs' Perceived Workload**
 2. **SART for Situation Awareness**
 3. **Apply Eye Tracking to evaluate ATCO's monitoring performance**
- **Discussions and Conclusion**
- **Q & A**

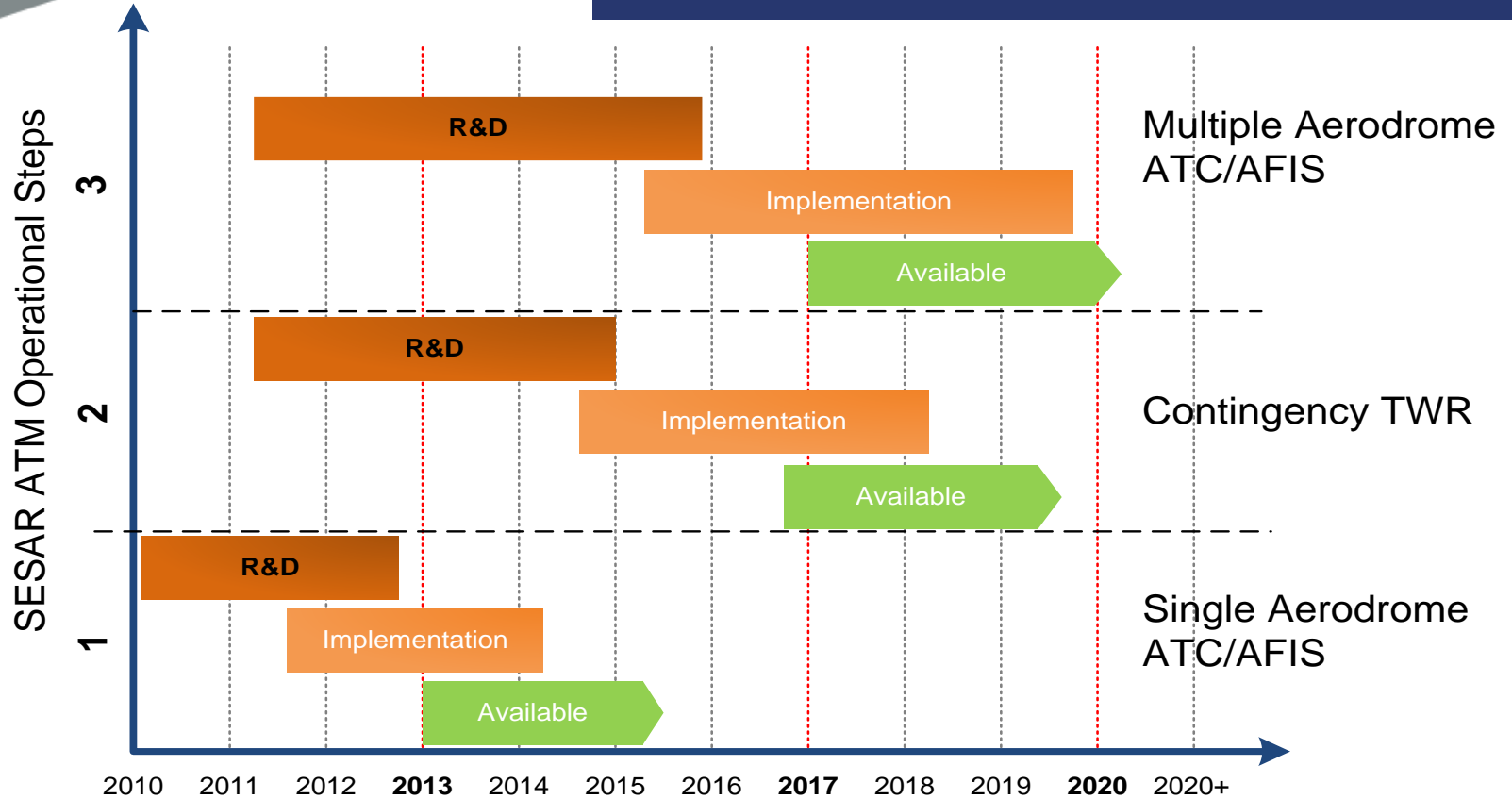
SESAR ATM Operational Step Timeline



UK's first Digital Air Traffic Control Centre opens at Cranfield

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Application of NASA-TLX to Evaluate ATCOs' Perceived Workload

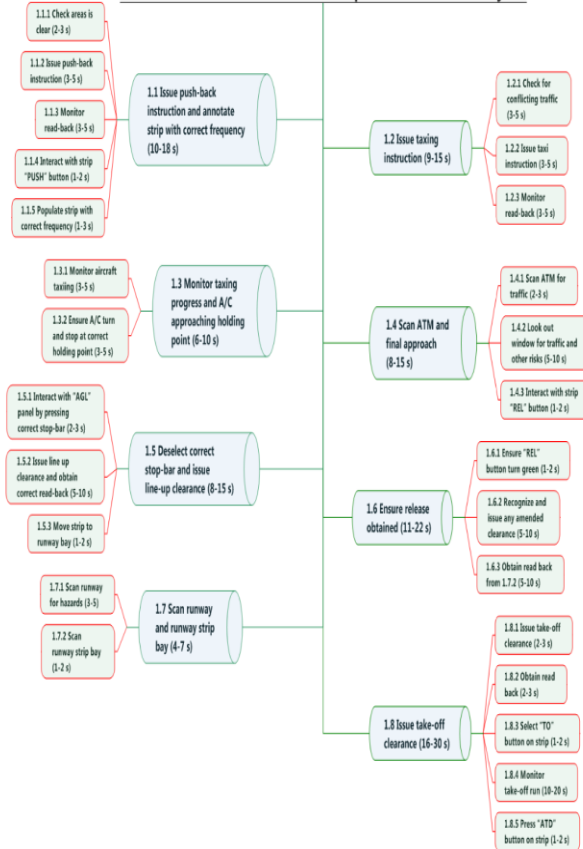


- Workload can negatively affect ATCOs' task performance and increase the error of operations, **how to measure it?**
- The NASA Task Load Index (TLX) is a popular technique for measuring subjective workload related to task performance
- The dependent variables consisted by **mental demand, physical demand, temporal demand, performance, effort and frustration**
- ATCOs were required to evaluate their perceived workload between local tower operations and remote tower operations (Pushback, taxi and departure from Runway 26)



Overall Goal of Task: Pushback, taxi and departure from Runway 26

Scenario 1: Pushback, taxi and departure from Runway 26



The task performance consisted with 8 sub-goals and 26 operational steps in need of 132 seconds to complete the overall task

1. Issue push-back instruction and annotate strip with right frequency (10-18 s)
 1. Check areas is clear (2-3 s)
 2. Issue push-back instruction (3-5 s)
 3. Monitor read-back (3-5 s)
 4. Interact with strip “PUSH” button (1-2 s)
 5. Populate strip with correct frequency (1-3 s)
2. Issue taxing instruction (9-15 s)
 1. Check for conflicting traffic (3-5 s)
 2. Issue taxi instruction (3-5 s)
 3. Monitor read-back (3-5 s)
3. Monitor taxing progress and A/C approaching holding point (6-10 s)
 1. Monitor aircraft taxiing (3-5 s)
 2. Ensure A/C turn and stop at correct holding point (3-5 s)
4. Scan ATM and final approach (8-15 s)
 1. Scan ATM for traffic (2-3 s)
 2. Look out window for traffic and other risks (5-10 s)
 3. Interact with strip “REL” button (1-2 s)
5. Deselect correct stop-bar and issue line-up clearance (8-15 s)
 1. Interact with “AGL” panel by pressing correct stop-bar (2-3 s)
 2. Issue line up clearance and obtain correct read-back (5-10 s)
 3. Move strip to runway bay (1-2 s)
6. Ensure release obtained (11-22 s)
 1. Ensure “REL” button turn green (1-2 s)
 2. Recognize and issue any amended clearance (5-10 s)
 3. Obtain read back from 1.7.2 (5-10 s)
7. Scan runway and runway strip bay (4-7 s)
 1. Scan runway for hazards (3-5)
 2. Scan runway strip bay (1-2 s)
8. Issue take-off clearance (16-30 s)
 1. Issue take-off clearance (2-3 s)
 2. Obtain read back (2-3 s)
 3. Select “TO” button on strip (1-2 s)
 4. Monitor take-off run (10-20 s)
 5. Press “ATD” button on strip (1-2 s)

T-test of ATCOs' Perceived Workload between Remote Tower and Local Tower Operations



Dimension	Towers	Mean	SD	T-Test				
				t	df	p	SE	Cohen's d
Mental demand	Remote tower	52.045	17.297	3.363	21	0.003	3.042	0.717
	Physical tower	41.818	15.472					
Physical demand	Remote tower	27.955	17.839	0.251	21	0.805	3.722	0.051
	Physical tower	27.045	19.002					
Temporal demand	Remote tower	50.227	13.756	4.491	21	0.000	2.986	0.957
	Physical tower	36.818	17.151					
Performance	Remote tower	67.045	18.104	2.776	21	0.011	3.520	-0.592
	Physical tower	76.818	21.852					
Effort	Remote tower	43.864	19.082	1.714	21	0.101	4.906	0.365
	Physical tower	35.455	18.575					
Frustration	Remote tower	37.045	20.099	4.356	21	0.000	2.765	0.929
	Physical tower	25.000	17.252					
NASA-TLX Total Score	Remote tower	46.212	9.473	2.935	21	0.008	1.949	0.626
	Physical tower	40.492	11.012					



Frequentis



SAAB

- ATCO has perceived significantly higher on **mental demand**, **temporal demand**, **frustration** and **lower performance** on the remote tower operation
- To maintain safe level of Performance ATCOs experienced higher workload which induced fatigue quicker
- However, **different tasks**, **interface design** and **operating systems** may have impacts to operators' perceived workload and SA (**SAAB vs Frequentis**)
- Furthermore, workload may induce fatigue and decrease SA, ANSPs have to find a solution to mitigate ATCO's **perceived workloads and fatigue**

Application of SART-10D to Assess ATCOs' Situation Awareness

Domains	Construct	Definition
Attentional demand	Instability of situation	Likelihood of situation to change suddenly
	Variability of situation	Number of variables that require attention
	Complexity of situation	Degree of complication of situation
Attentional supply	Arousal	Degree that one is ready for activity
	Spare mental capacity	Amount of mental ability available for new variables
	Concentration	Degree that one's thoughts are brought to bear on the situation
	Division of attention	Amount of division of attention in the situation
Understanding	Information quantity	Amount of knowledge received and understood
	Information quality	Degree of goodness of value of knowledge communicated
	Familiarity	Degree of acquaintance with situation experience

$$SA = \text{Understanding} - (\text{Demand} - \text{Supply})$$

- ATCO's SA including Attentional Demands, Supply and Understanding which affecting the safety of operations
- The situation awareness rating technique (SART) is a simplistic post-trial subjective rating technique
- SART allows operators to rate his/her SA by practical experiences on monitoring performance
- The main advantages of SART are easy to use and low cost

ATCOs' Situation Awareness between Physical Tower and Remote Tower Operations by T-Test



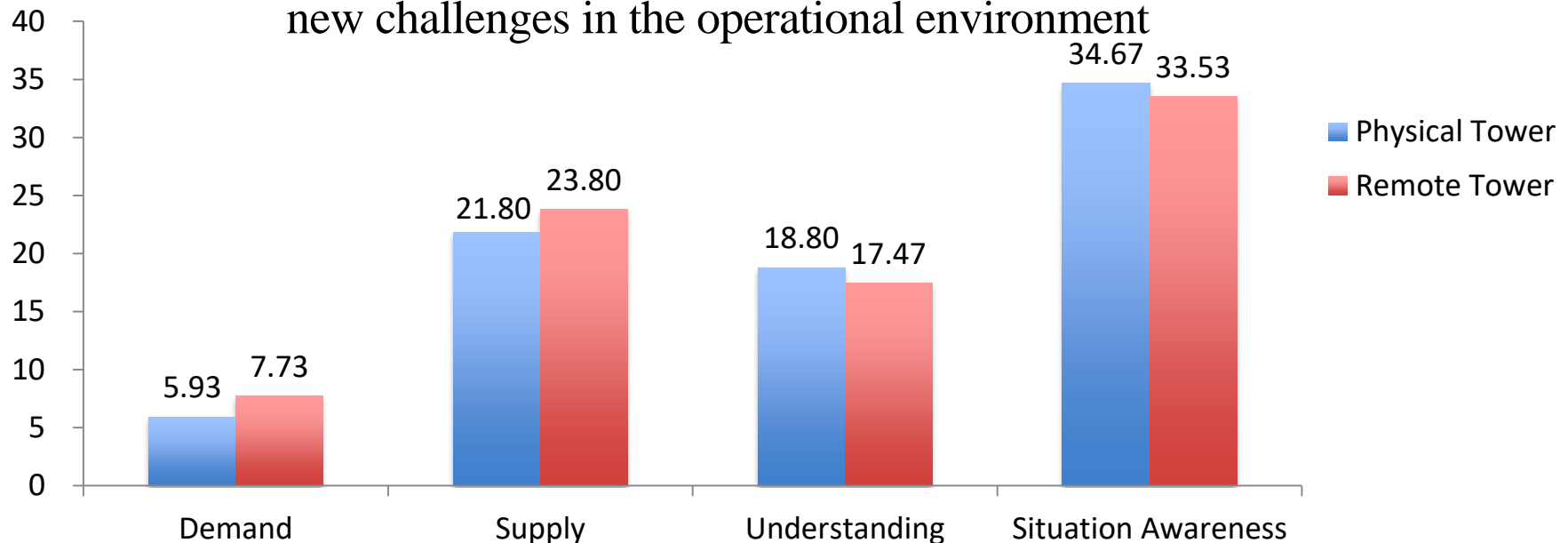
Variables	Design	Mean	SD	N	T-Test			
					t	df	p	Cohen's d
Demand	Remote Tower	7.73	1.98	15	3.60	14	0.003	0.93
	Physical Tower	5.93	1.53					
Supply	Remote Tower	23.80	1.37	15	2.69	14	0.018	0.69
	Physical Tower	21.80	2.34					
Understanding	Remote Tower	17.47	0.99	15	-3.45	14	0.004	-0.89
	Physical Tower	18.80	1.42					
Situation Awareness	Remote Tower	33.53	3.04	15	-1.18	14	0.258	-0.30
	Physical Tower	34.67	4.17					

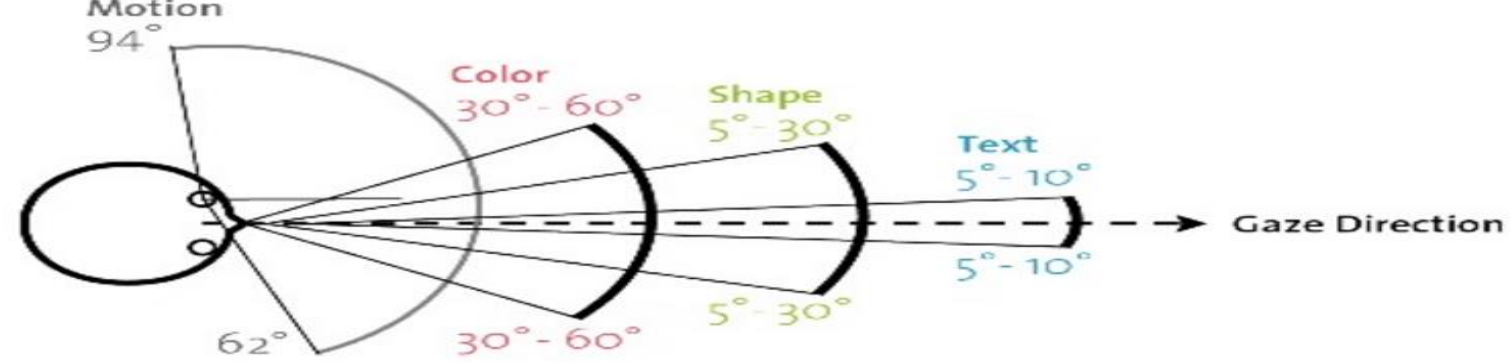
Results of SART

SA = Understanding - (Demand - Supply)

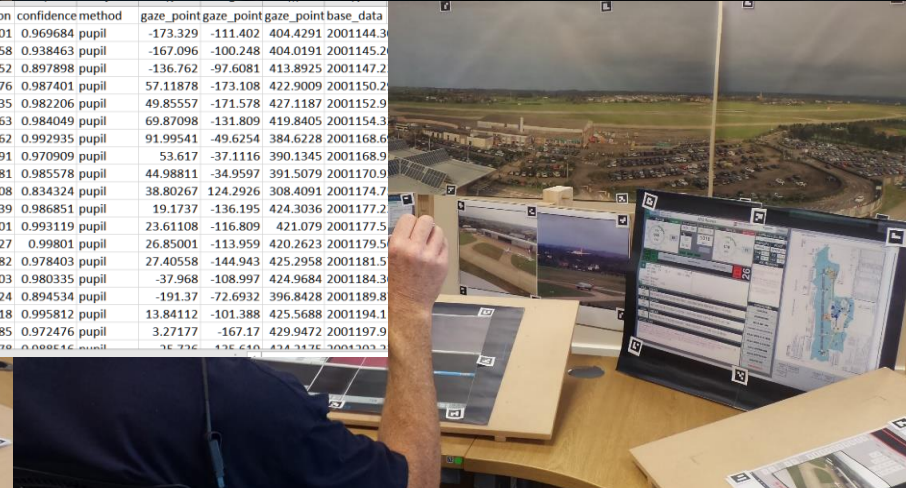


- Remote tower requires more attention distributions to different AOIs compared with Local Tower
- Remote tower provide more information to ATCOs which is good but increasing cognitive loads as well
- Significant differences on **Understanding**
- Human operator can adapt and adjust himself/herself to fit the new challenges in the operational environment





id	start_time	duration	start_frame	end_frame	norm_pos	norm_pos	dispersion	confidence	method	gaze_point	gaze_point	gaze_point	base_data
1	2001144	268.8	0	3	0.345086	0.688303	2.282601	0.969684	pupil	-173.329	-111.402	404.4291	2001144.3
2	2001145	1671.6	15	47	0.349168	0.671771	2.681658	0.938463	pupil	-167.096	-100.248	404.0191	2001145.2
3	2001147	537.6	54	65	0.378184	0.668043	2.892652	0.897898	pupil	-136.762	-97.6081	413.8925	2001147.2
4	2001150	201.6	122	127	0.566809	0.787099	2.869376	0.987401	pupil	57.11878	-173.108	422.9009	2001150.2
5	2001153	344.4	180	187	0.559672	0.783228	1.302335	0.982206	pupil	49.85557	-171.578	427.1187	2001152.9
6	2001154	814.8	207	222	0.581245	0.726576	2.506263	0.984049	pupil	69.87098	-131.809	419.8405	2001154.3
7	2001169	201.6	485	489	0.61368	0.596923	2.948462	0.992935	pupil	91.99541	-49.6254	384.6228	2001168.6
8	2001169	2007.6	489	527	0.57195	0.573739	2.921891	0.970909	pupil	53.617	-37.1116	390.1345	2001168.9
9	2001171	260.4	528	533	0.562379	0.569628	0.618981	0.985578	pupil	44.98811	-34.9597	391.5079	2001170.9
10	2001175	428.4	596	603	0.563254	0.221387	2.620708	0.834324	pupil	38.80267	124.2926	308.4091	2001174.7
11	2001177	201.6	642	648	0.531266	0.733779	3.007139	0.986851	pupil	19.1737	-136.195	424.3036	2001177.2
12	2001178	2041.2	649	689	0.536141	0.704807	2.956601	0.993119	pupil	23.61108	-116.809	421.079	2001177.5
13	2001180	512.4	689	700	0.539431	0.700516	2.293827	0.99801	pupil	26.85001	-113.959	420.2623	2001179.5
14	2001182	285.6	728	734	0.53916	0.746505	1.264382	0.978403	pupil	27.40558	-144.943	425.2958	2001181.5
15	2001184	226.8	759	763	0.474601	0.69019	0.714803	0.980335	pupil	-37.968	-108.997	424.9684	2001184.3
16	2001190	1327.2	872	899	0.324585	0.625802	1.728324	0.984534	pupil	-191.37	-72.6932	396.8428	2001189.8
17	2001194	226.8	961	967	0.526295	0.678024	2.949918	0.995812	pupil	13.84112	-101.388	425.5688	2001194.1
18	2001198	210	1038	1042	0.515563	0.776974	2.698485	0.972476	pupil	3.27177	-167.17	429.9472	2001197.9
19	2001203	260.6	1133	1133	0.487670	0.737053	2.037378	0.898516	pupil	35.726	135.640	434.3476	2001203.3



ATCO's Visual Parameters on HCI with RTM



ATCOs' projection of attention distribution among 7 AOIs

Descriptive statistics of average fixation duration

Descriptive statistics of average saccade amplitude

AOI ID	AOI	Mean(SD)
1	Lighting panel	4.77(2.96)
2	Schmid voice switch	5.00(2.88)
3	Flight strip	13.14(5.83)
4	ATM radar display	15.68(7.74)
5	AWOS	6.27(3.21)
6	PTZ control panel	10.32(8.28)
7	Out of Window	45.18(17.53)

AOI	Mean(SD)
Lighting panel	455.93(203.61)
Schmid voice switch	809.55(303.30)
Flight strip	444.96(158.90)
ATM radar display	744.74(160.87)
AWOS	661.73(269.81)
PTZ control panel	577.14(156.34)
Out of window	720.15(194.73)

AOI	Mean(SD)
Lighting panel	8.91(3.19)
Schmid voice switch	11.87(17.03)
Flight strip	10.16(3.83)
ATM radar display	6.46(1.62)
AWOS	5.80(2.15)
PTZ control panel	8.16(3.04)
Out of window	6.67(1.26)



Percentage of Attention Distribution: OTW is the Crucial Interface

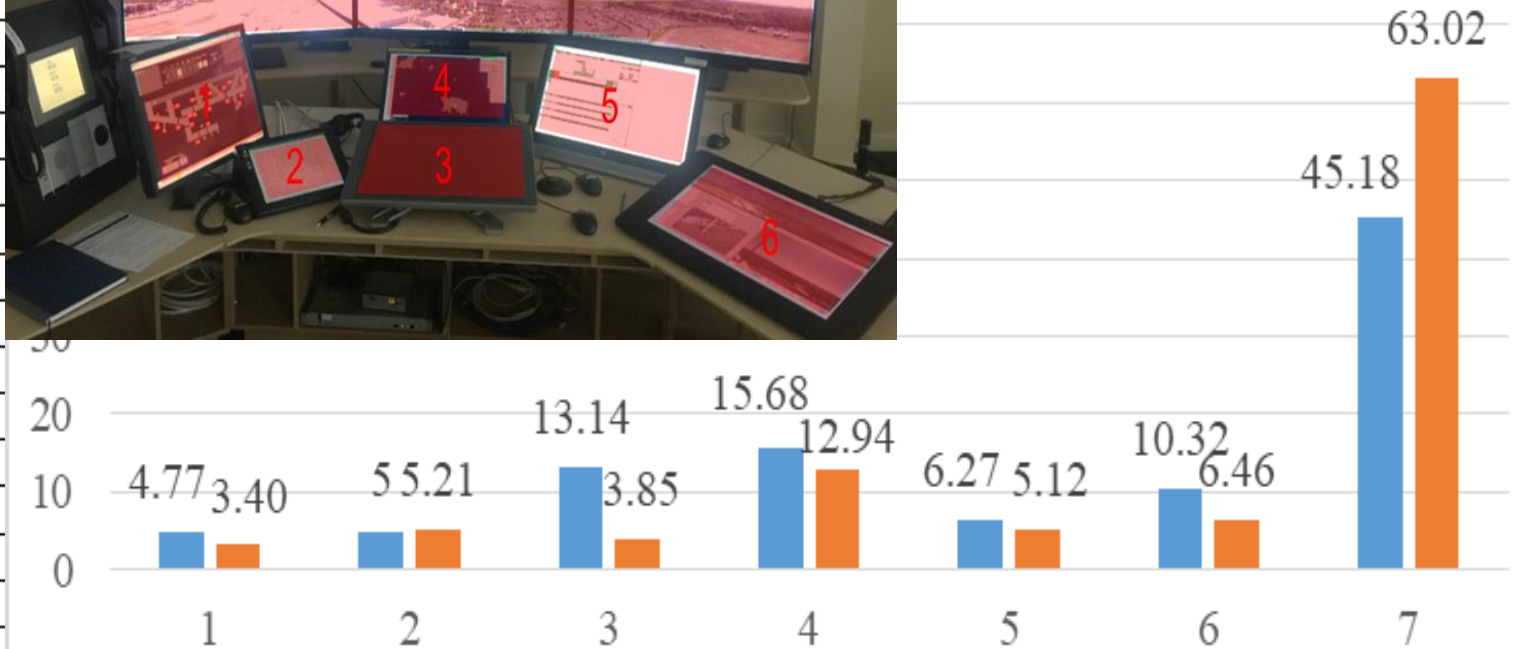


No.	1. Lighting (%)	2. Schmid (%)	3. EFS (%)	4. ATM (%)	5. AWOS (%)	6. PTZ (%)	7. OTW (%)
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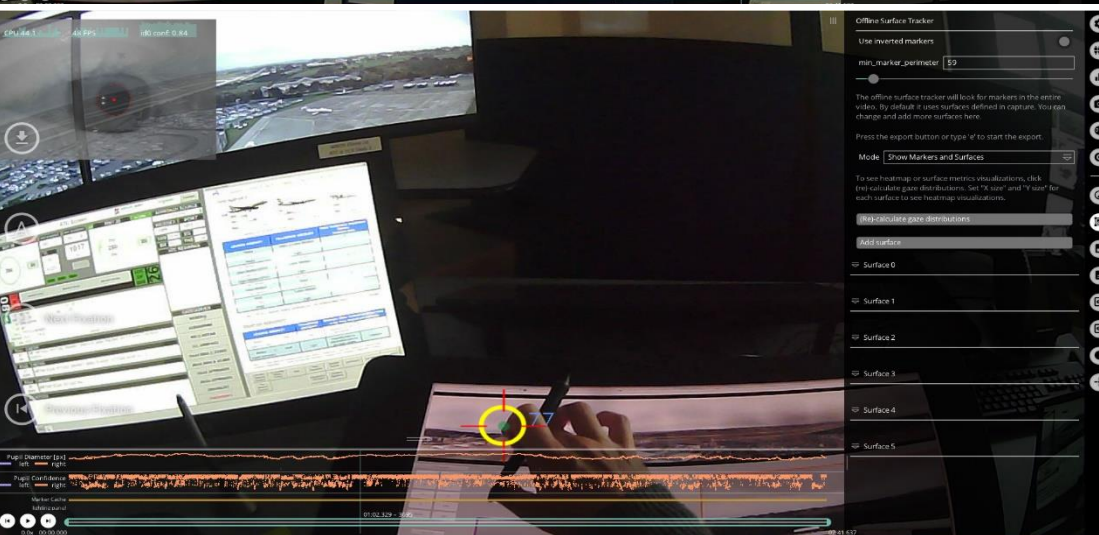
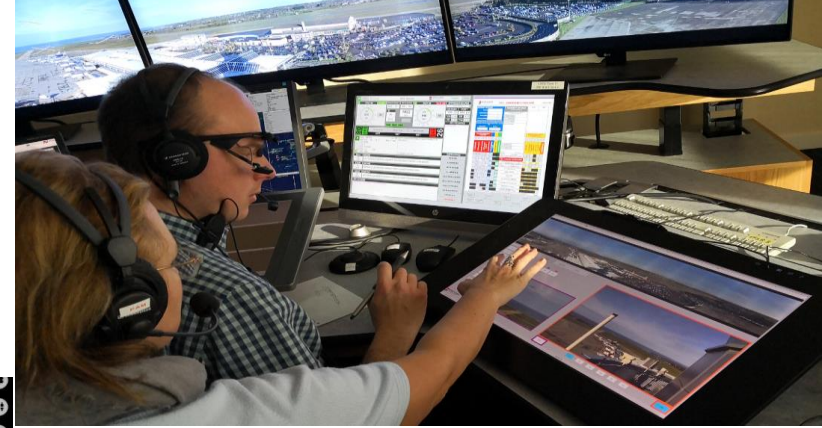
Percentage of attention distribution and total fixation duration on each AOI



■ Attention distribution
 ■ Total fixation duration



The Integration of OTW and PTZ may Facilitate ATCO's Task Performance



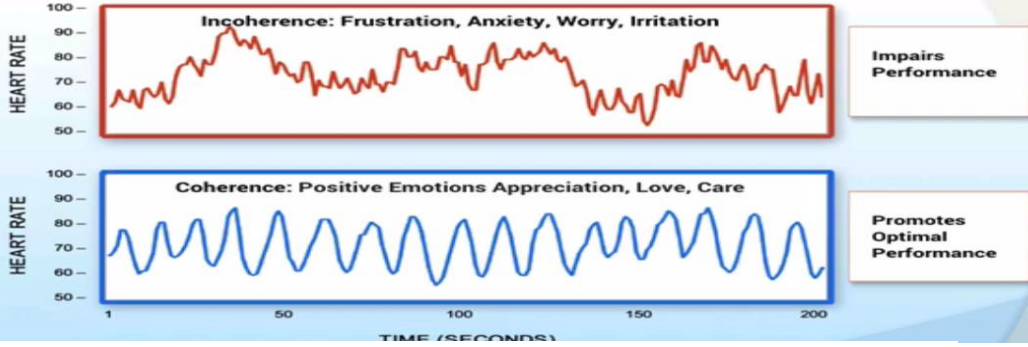
Increasing ATCO's SA

1. PTZ controls need to be on the OTW view rather than being out of main field of view.
2. PTZ presets need to be agreed. PTZ needs to be easy to slave to a position of interest.
3. Need more camera windows on PTZ. Need to know more about operations of PTZ.
4. Operating PTZ will involve a lot of head down time, not looking out the window.
5. The PTZ requires too much effort and attention to look for aircraft
6. PTZ screen too remote + removed from OTW main screen.
7. Label Tracking, PTZ, Integrated Labels.

What revision needed to be made on CWP

1. PTZ presets need to be better configured.
2. difficult to monitor downwind with PTZ.
3. PTZ should be in front, VCS on right of strips, AWOS further right and behind.
4. PTZ screen is a bit 'behind' us.
5. PTZ position to look at, too much of a stretch.
6. Movement tracking on PTZ would make a positive improvement.
7. PTZ not intuitive to use and too slow to update.
8. Joystick would be useful for PTZ.
9. Mice need to be labelled Names of PTZ better identified on screen and screen needs to be more in front of ATCO.

Workload Intervention: Psychophysical Coherence increasing Attention, SA and Decision-making



HRV Analysis - General Results

Pre2.txt - xx/xx/xx - xx:xx:xx

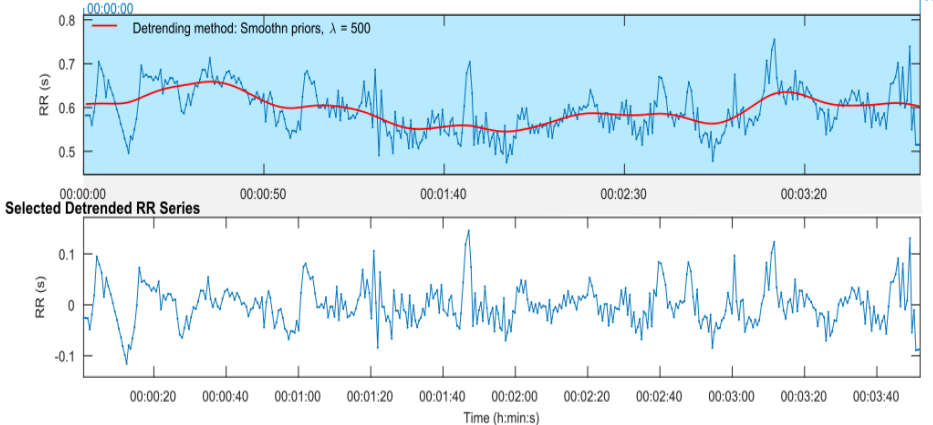
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IRV Analysis - General Results

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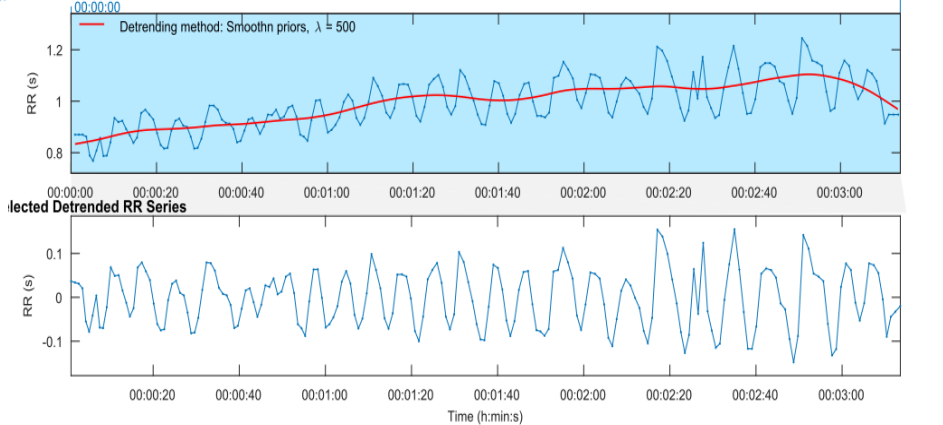
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RR Time Series: Automatic correction "Automatic correction": 6.91% of beats corrected)



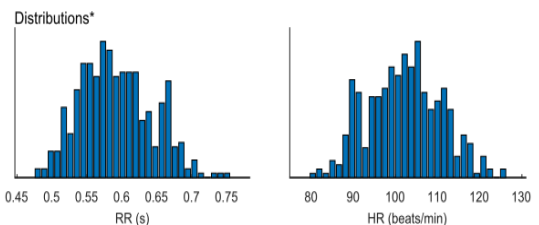
Results for a single sample

IRV Time Series: Automatic correction "Automatic correction": 2.04% of beats corrected)



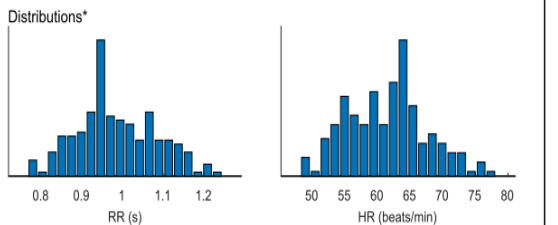
Time-Domain Results

Variable	Units	Value
Mean RR*	(ms)	592.0
STD RR (SDNN)	(ms)	38.7
Mean HR*	(beats/min)	101.34
Min/Max HR	(beats/min)	85.32/119.57
RMSSD	(ms)	37.2
NNxx	(beats)	57
pNNxx	(%)	14.6
RR triangular index		10.026
TINN	(ms)	197.0



Time-Domain Results

Variable	Units	Value
Mean RR*	(ms)	985.2
STD RR (SDNN)	(ms)	64.0
Mean HR*	(beats/min)	60.90
Min/Max HR	(beats/min)	50.80/74.83
RMSSD	(ms)	58.3
NNxx	(beats)	73
pNNxx	(%)	37.4
RR triangular index		15.077
TINN	(ms)	289.0



General Discussion



- ATCO's attention, situation awareness and performance can be affected by subjective perceived workload and **emotional response**
- Be aware of the new technology may induce new HCI issues and increasing perceived workload (**senior vs junior**)
- The findings are valuable for both ATCO's **training, certification, and system design** on RTM
- ATCO's perceived workload, monitoring performance, SA and fatigue needed further research for future RTO
- Further thought, technology shall increase not only human performance but also **wellbeing**



Human Factors in Aviation Safety 9 November - 10 November

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