



Australian Government
Department of Defence
Science and Technology



Increased Information Integration in Future Undersea Command and Control

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Maritime Control Room research

- Human Sciences & Information Integration, Undersea Command and Control, DST



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Research Goals

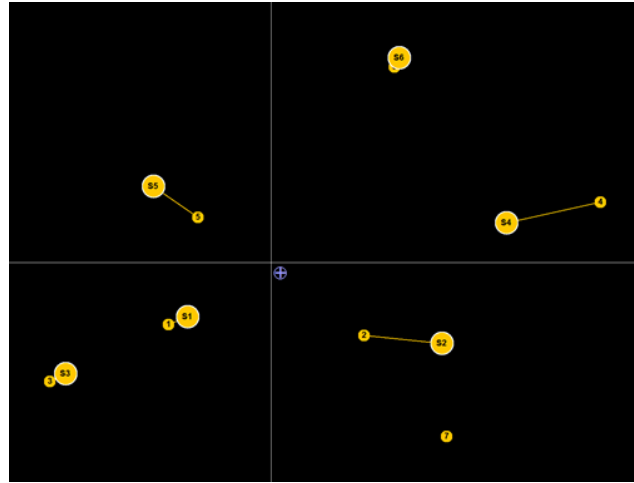
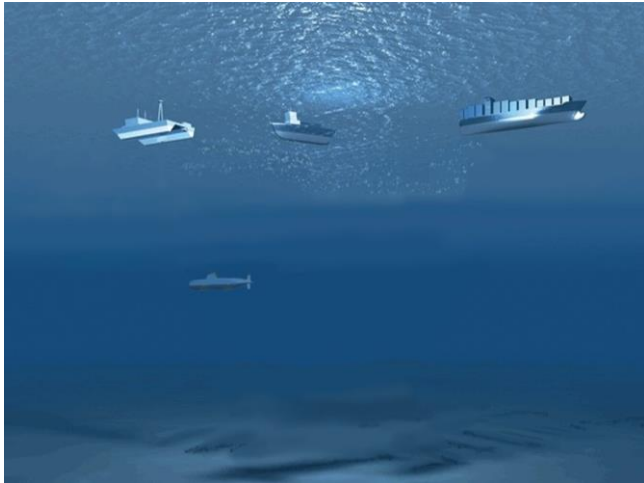
- Develop robust measures to assess teamwork & team performance.
- Inform innovation in respect to team composition and technology design.
- Inform future higher-fidelity usability testing.



Control Room Use Simulation Environment (CRUSE)

Team Performance

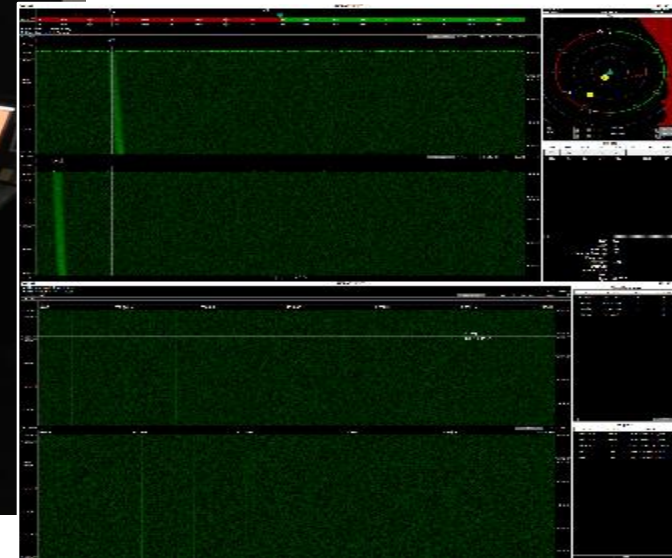
- Developing the Tactical Picture
- Integrate information to localize contacts
- Human agents, console display (machine) agents, and software agents



Sonar 1 and 2



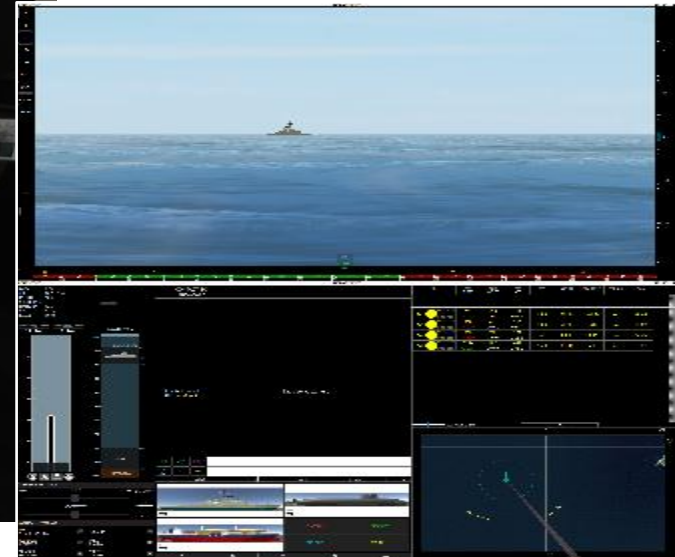
Detect and classify contacts



Optronic



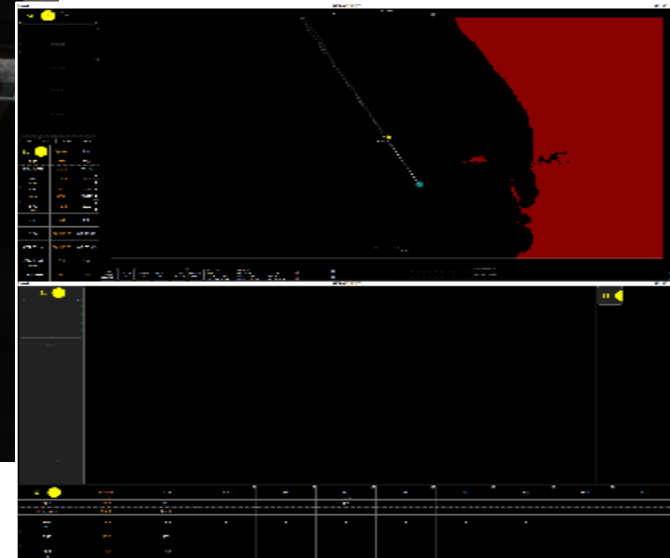
Classifies,
estimates range
and course



Target Motion Analysis 1 and 2



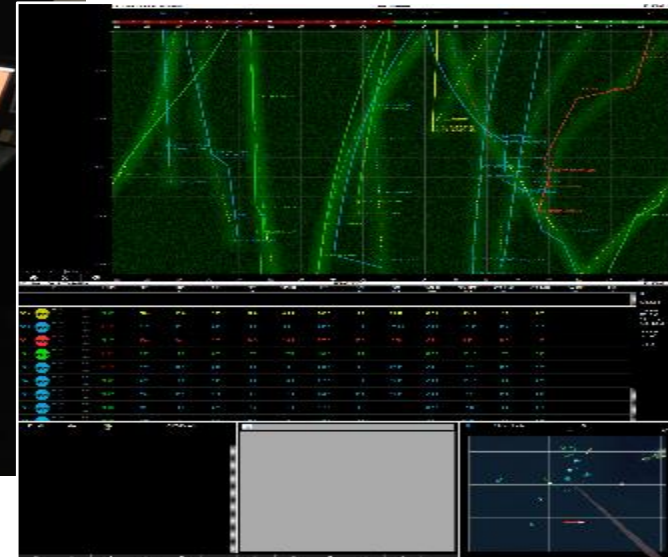
Estimate range,
course and speed
(solution)



Track Manager



Manage, prioritise
and quality-check



Study 1: Information Integration

Low information integration

- Analogue of the current, more stove-piped systems.
- Machine-centred philosophy; the information a sensor/operator generates is displayed on the associated dedicated console.
 - Example; bearing and the bearing rate of change available on the sonar console, but absent from the TMA console.
- The results of information processing by the operator remain on that console on which it was generated.
 - Sonar's annotations (e.g. speed or classification).
 - Track-manager's colour coding of the contacts by their classification.

Study 1: Information Integration

High information integration

- Based on the DST conducted Cognitive Work Analysis and User-Centred Design Thinking Workshops.
- More functional design, providing the operator the information they need regardless of source or who processed it.

	High Integration	Low Integration
Geoplot	All consoles and command screen	Track manager display only
Bearing rate	Available on TMA console	Communicated verbally
Classification	Color-coded on all consoles	Communicated verbally
Sonar trace position	Available on command screen and optronics	Communicated verbally

Study 1: Information Integration

Will higher integration benefit situation awareness, workload and team performance?

- High integration eliminates the need for the operator to have to ask for and wait for information that they require (information is immediately available).
- Potential for greater amounts of information available on highly integrated consoles to be visually distracting/overload?
- The need to verbalise more information with low integration likely serves as a point of reference for those in the control room (contacts of interest; presence of conflicting information).
- Potential for temporal dissonance with higher integration?

Study 1

NOVICES

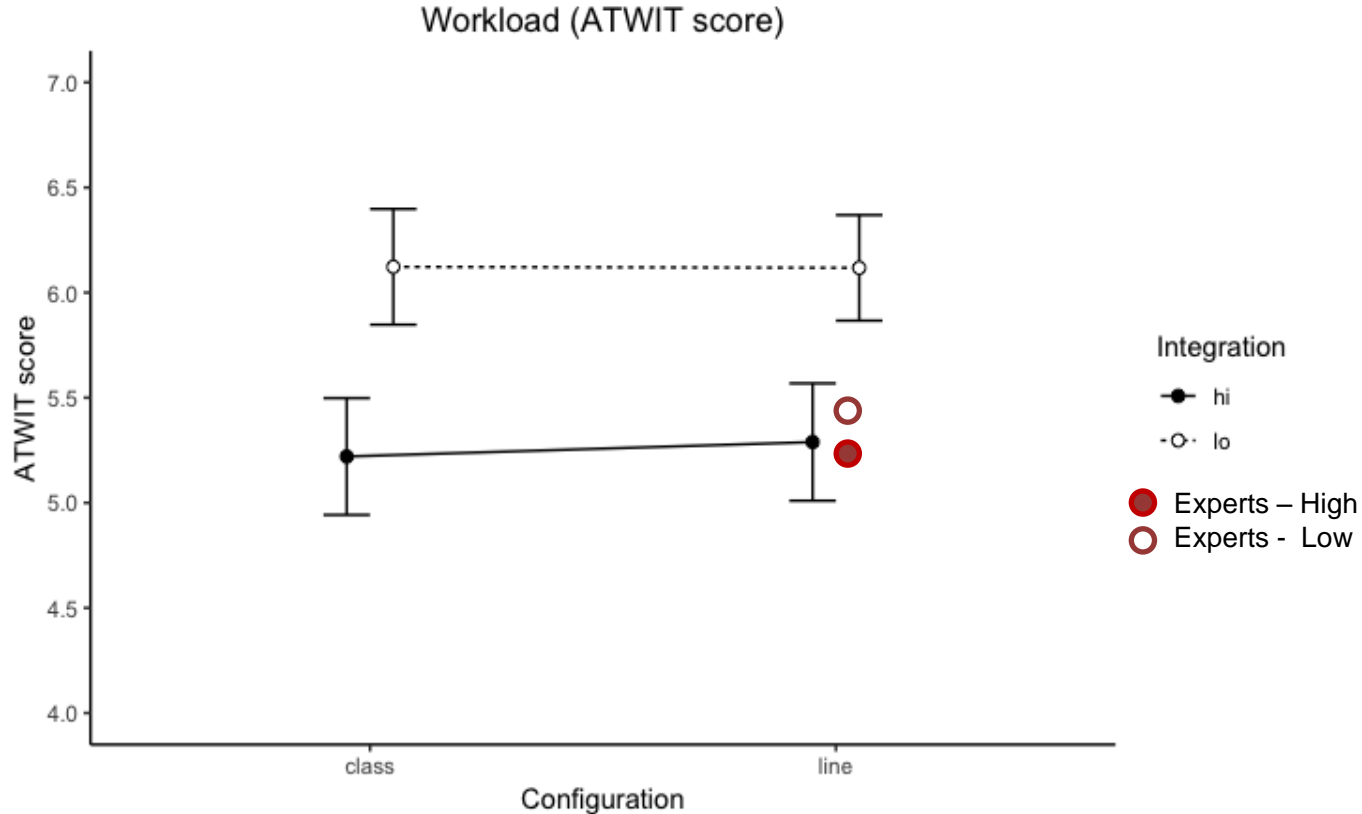
- Recruited from UWA community pool
- 9-hour experiment over one day
- 16 teams of 6 novices (38 males, 57 females)
- Average age = 29 years

EXPERTS

- Recruited from HMAS STIRLING
- 6-hour experiment over one day
- One team of 6 (all male)
- Average age = 30 years

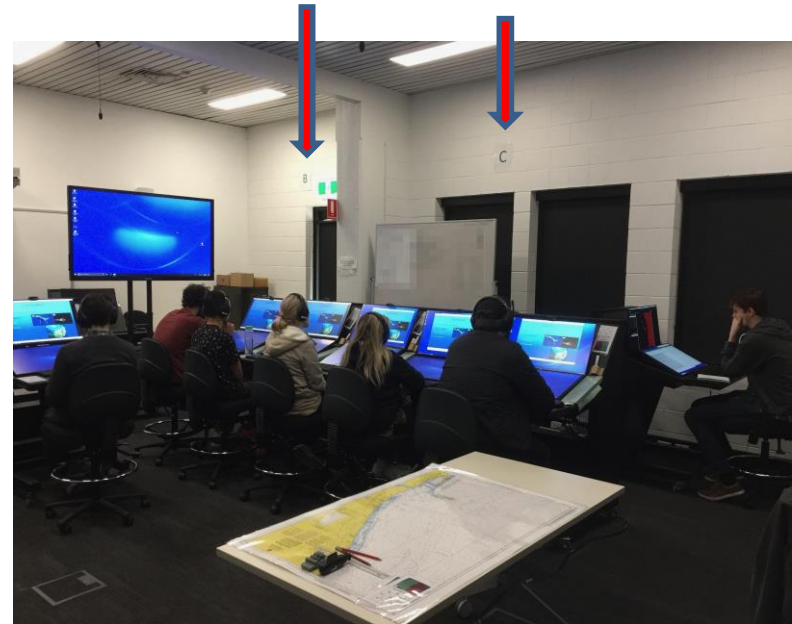


Subjective Workload (ATWIT)



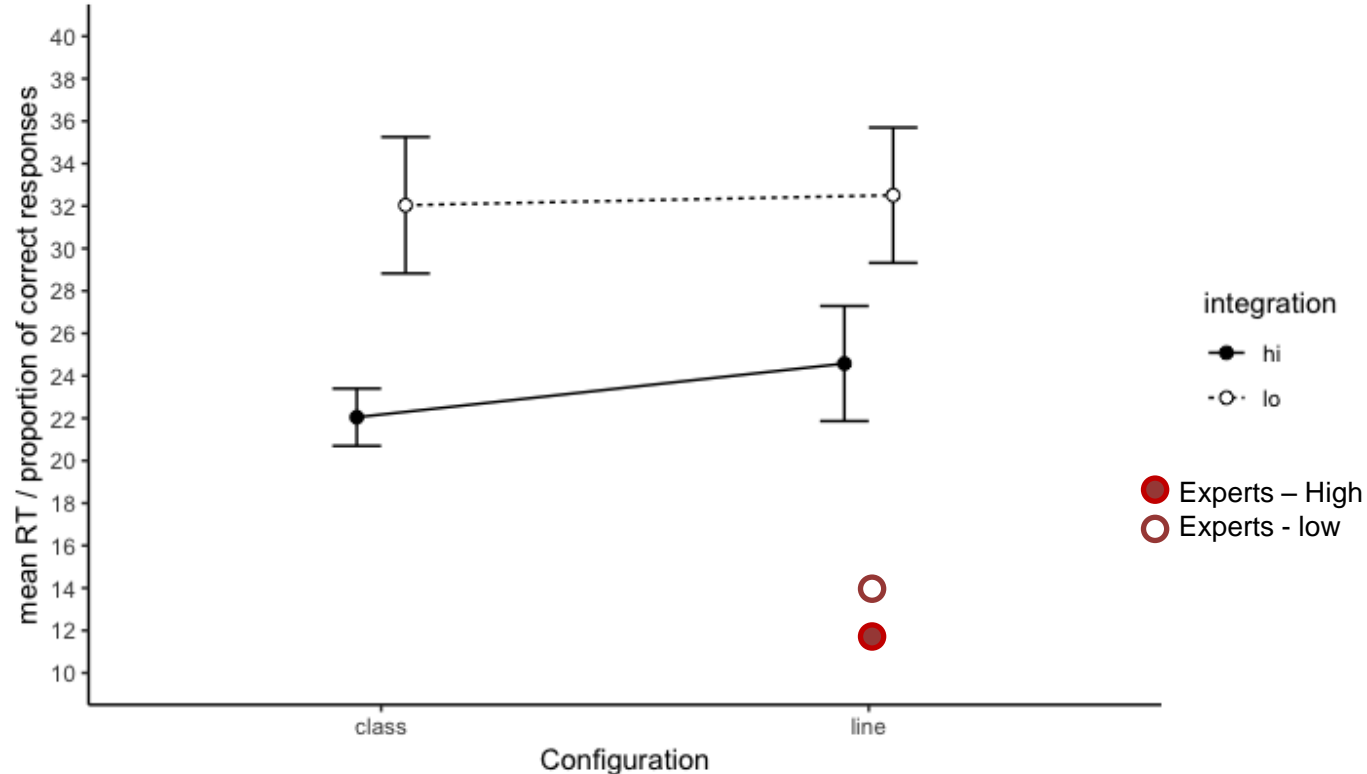
Situation Awareness (SPAM)

Item	Time	Question
1	3.30	Where is the most recently detected contact?
2	6.00	Where will the Merchant B ship be in ten minutes?
3	11.00	Where is the closest merchant ship?
4	16.30	Where is the most recently detected contact?
5	21.00	Which vessel will pass behind us in about 10 minutes time?
6	23.30	How many merchant vessels are we currently tracking?
7	29.00	Where will the merchant ship at around Green 25 be in 10 minutes?
8	34.00	Where is the most recently detected contact?
9	38.00	Where will the fishing vessel at around Red 15 be in 10 min?
10	43.00	What type of vessel is the closest?
11	47.00	Where is the most recently detected contact?
12	53.00	Where will the warship at around Red 20 be in 10 minutes?
13	58.30	Where will the merchant ship at around Red 130 be in 10 minutes?



Situation Awareness

Situation Awareness (Adjusted SPAMRT)



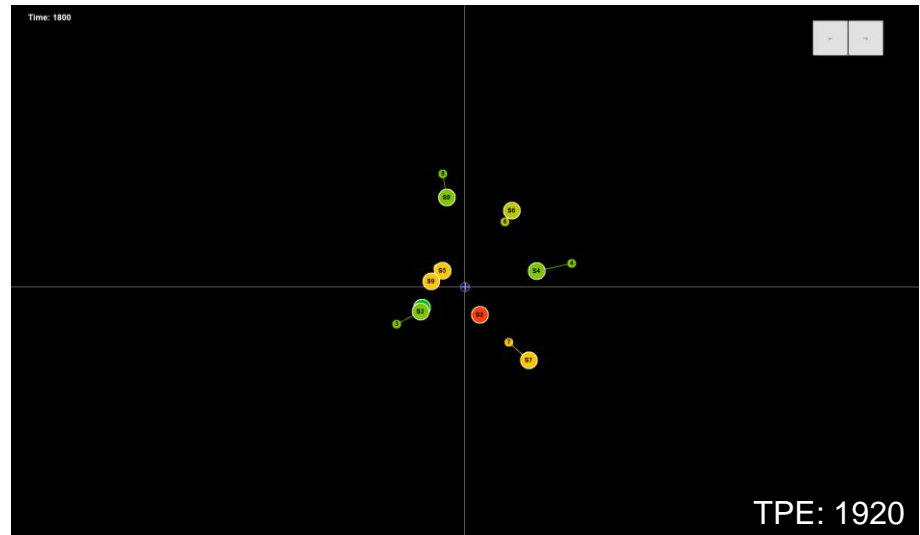
Team Performance Metrics

- Tactical Picture Error (TPE)
 - Position error of all contacts
 - At each point in time
 - Penalty for delaying solution
 - Weighted by priority

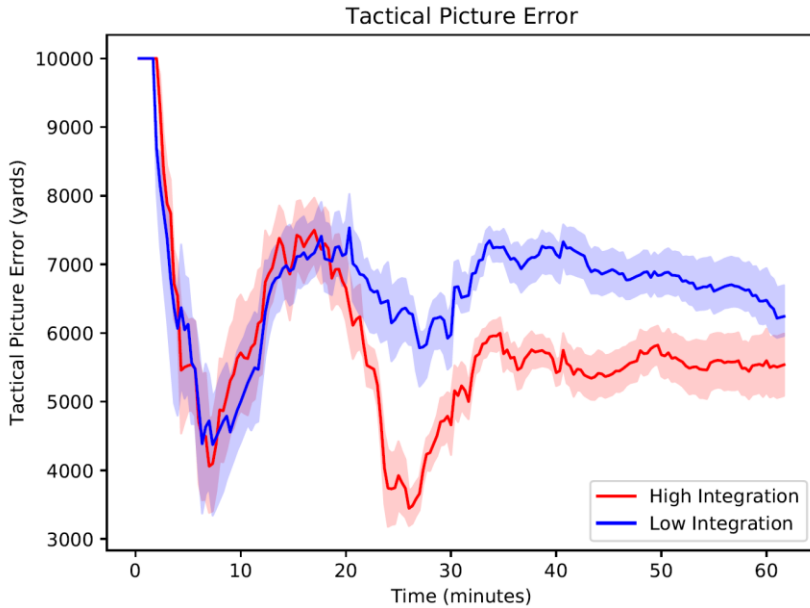
	Priority weights		
	1	2	3
Classification	Merchant	Fishing	Warship
Range	> 10 kyrds	5-10 kyrds	< 5 kyrds
Course	Opening		Closing
Behaviour	Steady course		Zigging
Total Weight	<i>Product of all weights</i>		

AIO Priorities & Values:

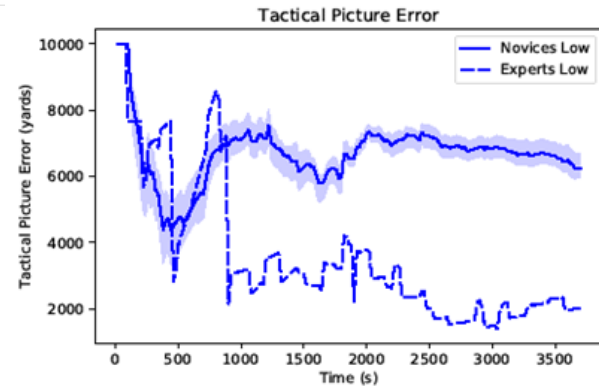
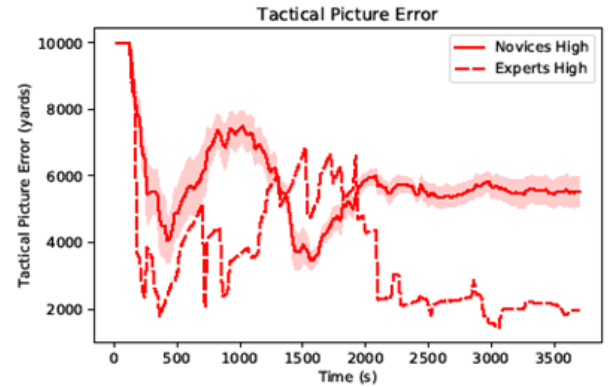
- Completeness
- Accuracy
- Timeliness
- Appropriateness for tactical picture



Novices by Integration



Novices vs. Experts

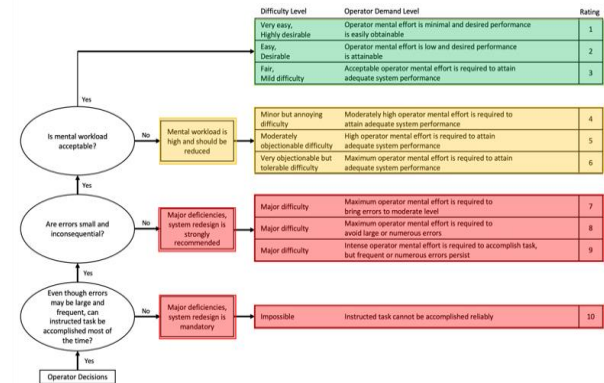


Study 1: Summary

- ✓ Measures were sensitive to information integration.
- ✓ Developed algorithms to characterise team performance.
- ✓ Subjective workload measures showed evidence of convergent validity.
- ✓ Suitable research platform for use with expert teams.
- ✓ Evidence that high information integration allowed operators to better maintain SA and build a more accurate tactical picture, and that they required less cognitive effort to do so.

STUDY 2

- Increase Task Load
- Modified the information integration designs
- Detection Response Task (DRT) to objectively measure workload
- Modified Cooper-Harper to assess system usability/workload
- Subjective team workload (Coordination Demand, Communication Demand etc.)
- Refined situation awareness measure
- Prediction of team performance



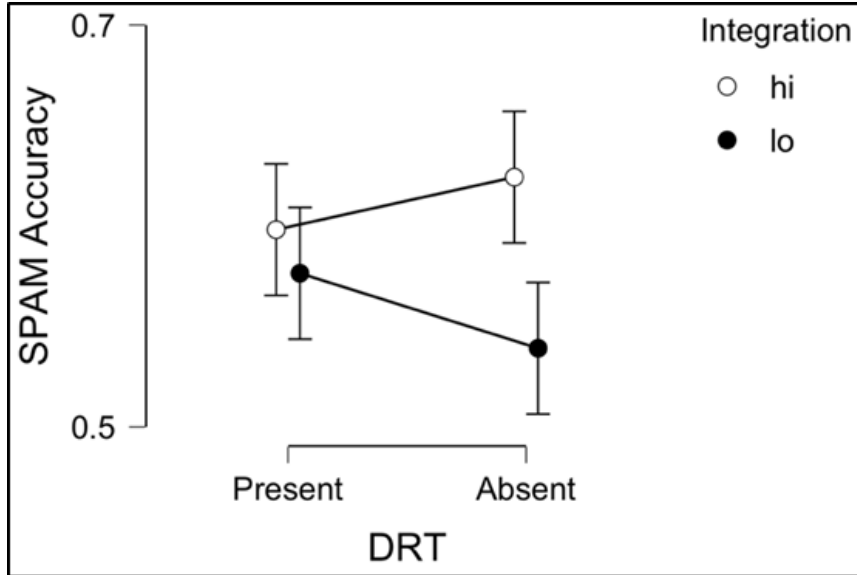
Study 2

NOVICES

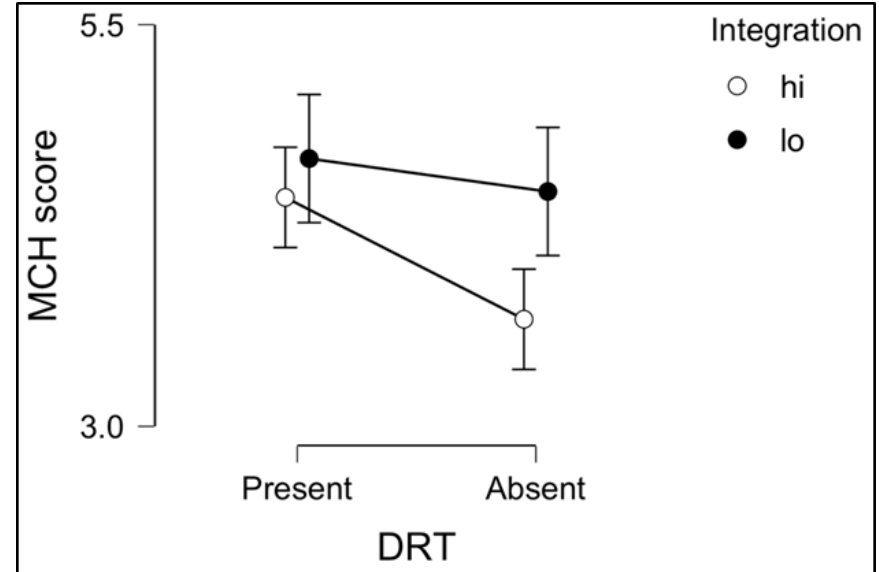
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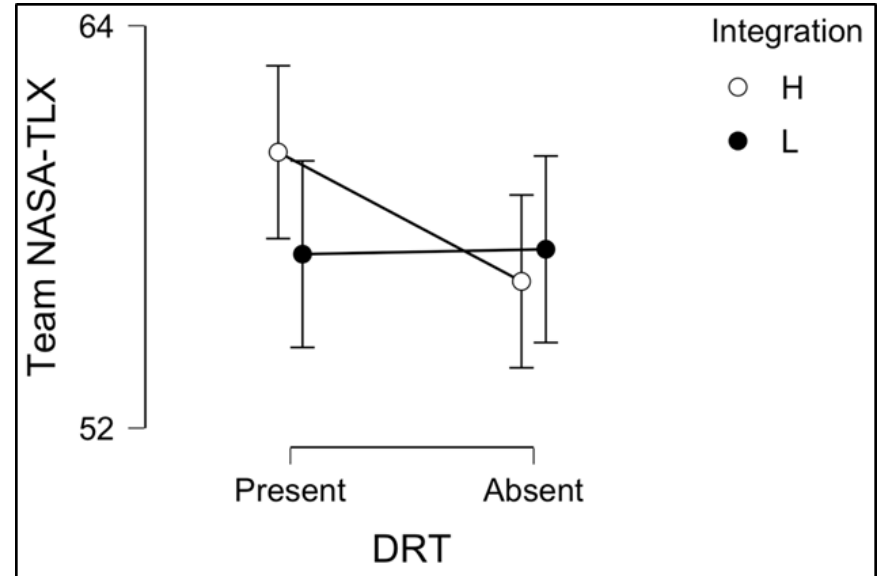
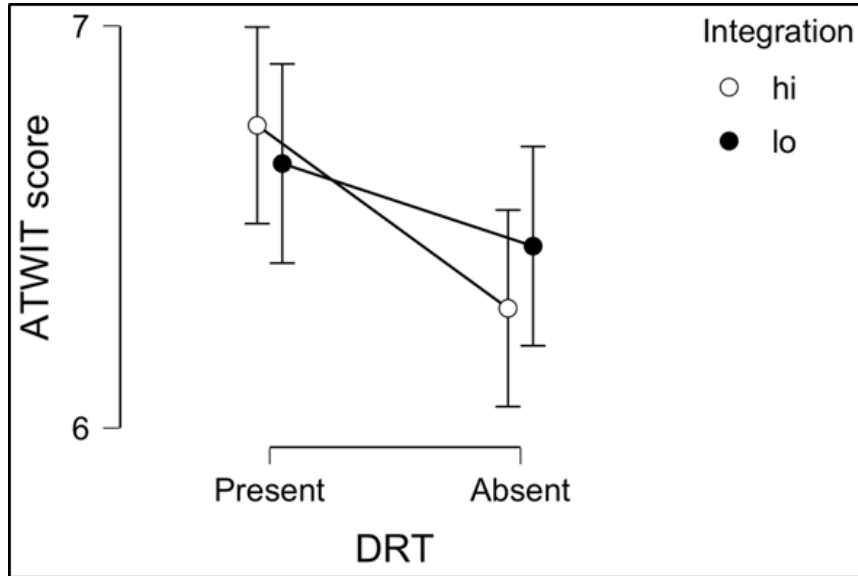
Situation Awareness



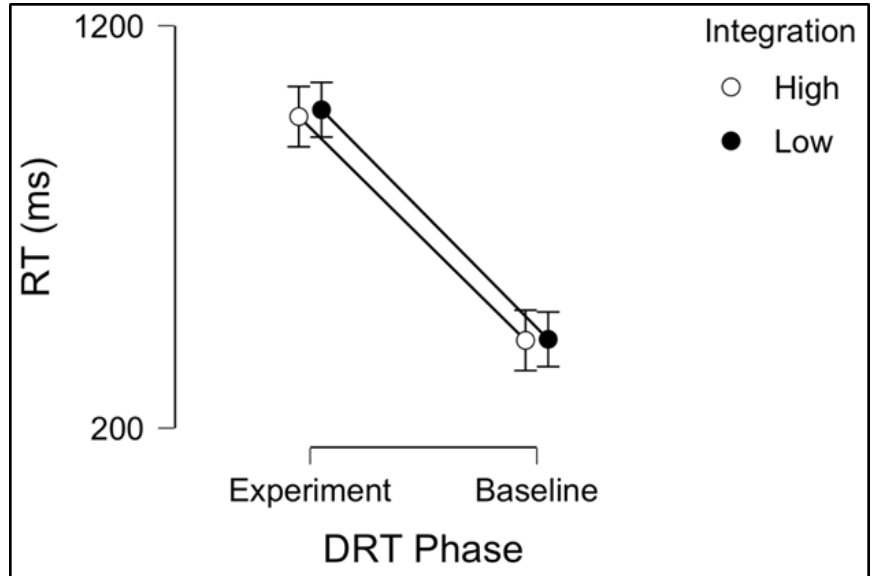
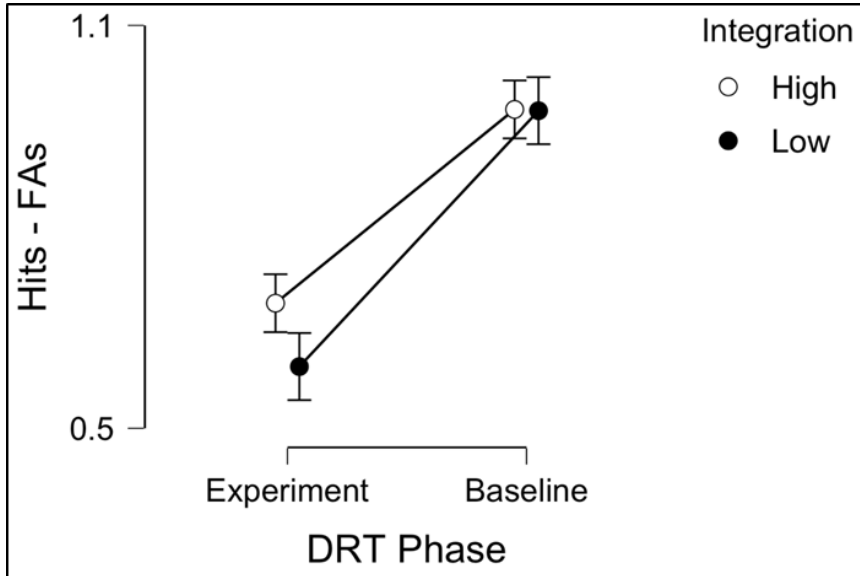
Workload/Usability



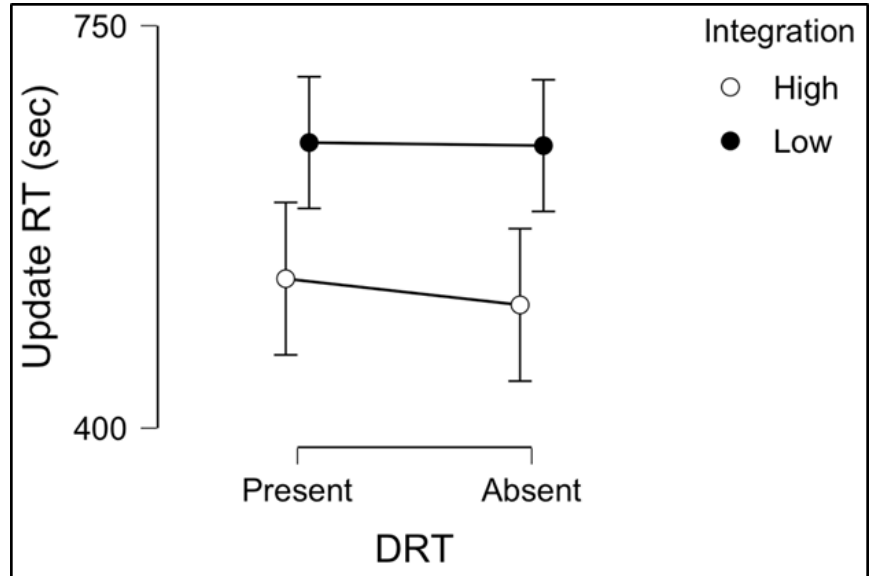
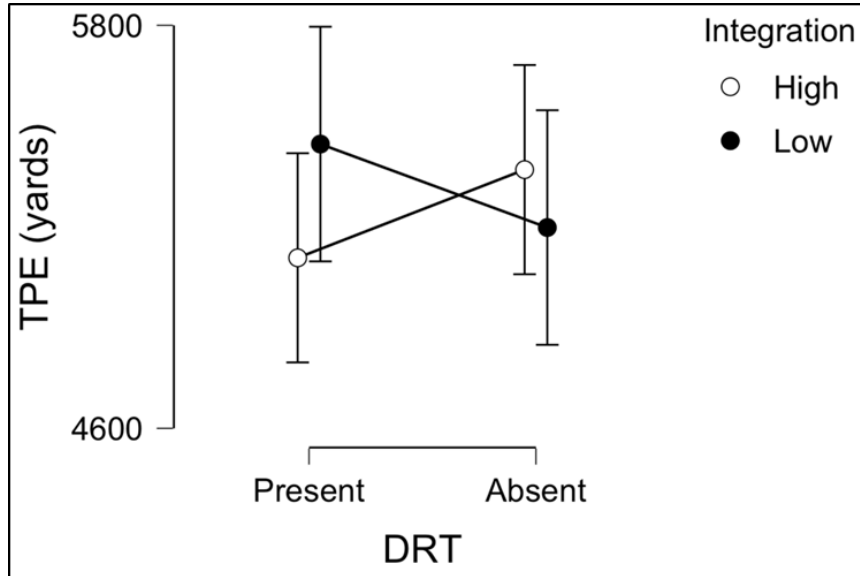
Subjective Workload



Objective Workload (DRT)



Team Performance



Study 2: Summary

- Sensitive objective measure of workload (DRT) to integration.
- Information integration: replicated some findings from Study 1
 - Situation Awareness and Modified Cooper-Harper (subjective workload)
- Did not replicate other subjective workload findings.
- Did not replicate all the effects of integration on team performance from Study 1.
- Differences in information integration designs across the studies.

Predicting Team Performance

seconds	no. of contacts	CLASSIFICATION EVENTS	SACAT	ATWIT	LOCATION:
30	1	1=1-241	SA - 209	A - 50	COCKATOO
60	2	2=e-270		A - 110	
90	4	3=1-304	A - 170	A - 110	
120	4	4=1-321	A - 195	A - 170	
150	7	5=360	SA - 229	A - 170	
180	7	6=1-383		A - 195	
210	7	7=e-420	A - 410	A - 170	
240	7	8=f-443	A - 470	A - 170	
270	7		A - 530	A - 170	
300	7		A - 590	A - 170	
330	7		A - 650	A - 170	
360	7		A - 710	A - 170	
390	7		A - 739	A - 170	
420	7		A - 830	A - 170	
450	7		A - 860	A - 170	
480	7		A - 950	A - 170	
510	7		A - 1010	A - 170	
540	7		A - 1070	A - 170	
570	7		A - 1130	A - 170	
600	7		A - 1190	A - 170	
630	7		A - 1250	A - 170	
660	7		A - 1305	A - 170	
690	7		A - 1370	A - 170	
720	7		A - 1431	A - 170	
750	7		A - 1490	A - 170	
780	7		A - 1550	A - 170	
810	7		A - 1610	A - 170	
840	7				
870	7				
900	7				
930	7				
960	7				
990	7				
1020	7				
1050	7				
1080	7				
1110	7				
1140	7				
1170	7				
1200	7				
1230	7				
1260	7				
1290	7				
1320	7				
1350	7				
1380	7				
1410	7				
1440	7				
1470	7				
1500	7				
1530	7				
1560	7				
1590	7				
1620	7				

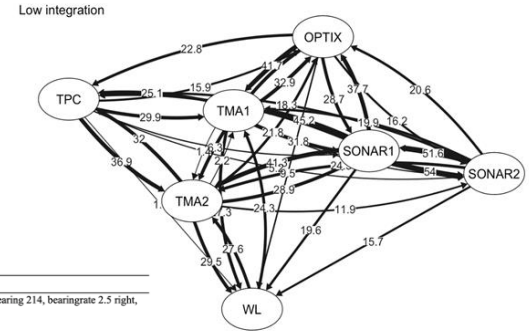
Event Analysis of Systemic Teamwork (EAST)

Neville Stanton & Aaron Roberts (U. Southampton)

Paul Salmon (U. Sunshine Coast)

- Social networks
- Information networks
- Task networks

Workflow, bottlenecks.



TimeZulu	From	To	Content
00:00:11	Sonar1	All	All positions, Sonar1, new contact, bearing 214, bearingrate 2.5 right, designated Sierra1
00:00:23	TPC	TMA1	TMA1, TrackManager
00:00:25	TMA1	TPC	Copy that
00:00:26	TPC	TMA1	Take Sierra1
00:00:29	Optix	All	All positions, Optix, have visual confirmation on Sierra1, ATB approximately 90 starboard
00:00:42	Sonar1	All	All positions, Sonar1, Sierra1 seems to be possible merchant B
00:00:52	Optix	All	Optix, all positions, can confirm visually, Merchant B
00:01:00	Sonar2	All	All positions -
00:01:00	TMA1	Optix	Optix, this is TMA1, just wondering if I can get a range on Sierra1
00:01:10	Sonar2	All	All positions, Sonar 2, Sonar holds a new contact bearing 081, bearingrate 0.1 right, designated Sierra2
00:01:23	TPC	TMA2	TMA - TMA2, take Sierra2
00:01:29	TMA2	TPC	Roger that
00:01:33	TPC	Optix	Was there a range on Sierra1?
00:01:36	Optix	TPC	Optix, Sierra1 - just calculating now
00:02:21	Sonar2	All	All positions, Sonar 2, updating report on Sierra2, classified as a possible warship
00:02:21
01:00:29	Optix	TPC	That was Sierra15?
01:00:31	TPC	Optix	Yeah, Sierra15 at red 30
01:00:37	TMA2	WL	WatchLeader, TMA2, update on Sierra13, bearing 257, range 4.6 kiloyards, course 160, speed 16.9 knots, bearingrates match
01:00:51	Optix	TPC	No visual for Sierra15, only Sierra9 which is just at the horizon
01:00:57	TPC	Optix	Alright, thanks

Future Research Directions (2020-2022)

Future Submarine Project

- Visual sensor HMI and shared visual imagery
- Use of off-board vehicles such as external drones and sensors
- Command level centralised information integration tools
- Automation (e.g., periscope auto tracking and cueing)

Network for Undersea Decision Superiority

- Individual differences in operator cognitive capacity and social cue utilisation
- Objective workload measurement and predicting team performance
- Building research capability in this area of research

Future Measures of Operational Performance?

Team inputs

- Scenario/mission
 - Return to periscope depth
 - Inshore operations
 - Transit
 - Periphot



Photo Credit: www.navy.gov.au

Team mediators

- Command decision-making
 - Naturalistic
 - Satisficing
- Team de-confliction, cross-checking

Team outputs

- Mission success
- Collision avoidance
- Counter detection
 - Periscope exposure time
 - Sonar counter-detection
 - Detection of go-deep line breach
- Navigational planning
 - Planning CPA
- No-go decision points

Thank you