The Effect of a Shared Tactical Picture on Distributed Decision Making in a Maritime Identification and Classification Task

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Declaration

This dissertation contains no material that has been accepted for the award of any other degree or diploma in any University and that, to the best of my knowledge, contains no materials previously published except where due reference is made.

I give permission for the digital version of my dissertation to be made available on the web, via the University's institutional digital repository, the Library Search and also through web search engines, unless permission has been granted by the School to restrict access for a period of time.

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December 2022

Statement of Contribution

I conceived the idea in collaboration with my supervisors from the Defence Science and Technology Group. I developed the idea for the experimental design and created the experiment "game" on the software program SGC, developed by the Defence Science and Technology Group. I steered Swordfish contractor Software Engineers at the Defence Science and Technology group to transform the "game" into a program that could be run across multiple computers over a local internet connection, and that could have data extracted from it. I created the experimental and analysis methodology in collaboration with my supervisors at both the University of Adelaide and Defence Science and Technology Group. I completed all data collection, analysis and discussion independently, with some review from supervisors and additional Defence Science and Technology staff. Prior to analysing the data, a colleague from the Defence Science and Technology Group helped create the data frame.

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(Title Page for journal submission to Journal of Cognitive Engineering and Decision Making – please note some details have been excluded/amended to preserve anonymity)

The Effect of a Shared Tactical Picture on Distributed Decision Making in a Maritime Identification and Classification Task

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Abstract

Being able to accurately classify and identify unknown vessels in a timely manner is critical in the maritime Defence context. Distributed decision making is a process where multiple people who are not co-located work together on a given task. Research has investigated both the effect of information availability and cognitive load on classification tasks but is limited in the distributed decision making context. This study investigated the benefits of using a common tactical picture over multiple local tactical pictures. A mixed methods approach was used, where 14 pairs of participants completed an identification and classification and then completed a qualitative survey on their strategies. In one condition, participants had their own local tactical picture, and needed to communicate to combine information and complete the task. In the other condition, both participants had access to a common tactical picture, where all information required to complete the task was presented to both participants. Results indicated that the benefits of a common tactical picture were improved accuracy (*Mdn* correct = 33%, *Mdn* correct = 27%). NASA TLX scores showed participants felt that they had to use more effort in the local tactical picture condition (*Mdn* = 70, *Mdn* = 62.5). Qualitative themes indicated that the benefits of using a common tactical picture allowed teams to dynamically share workload. The implications of this study involve the development of team structures that facilitate expert teaming.

Chapter 1: Introduction

1.1 Rationale

In high-stakes environments such as military operations, decision making is a process that can have considerable consequences, and is even more complex when engaged in as a team. An important aspect of military operations involves the sharing of sensor information to help teams navigate the environment and aid effective coordination and decision making between multiple people.

Decision making is the process of identifying and choosing between alternatives that best fit with the decision maker's goals, objectives, values and desires (Harris, 1998). Individual decision making occurs with one person making a decision based on multiple choices, whereas team decision making involves the collaboration of multiple people (Cannon-Bowers & Salas, 1998). Team decision making can be challenging, because there needs to be a synchronisation of actions, communication, and team member monitoring to work towards the common goal. These are known as team enabling behaviours (Hanna & Richards, 2018).

Distributed decision making (DDM) expands on team decision making by acknowledging that team members might not be co-located (Townsend et al., 1998), adding additional challenges. Distributed teams rely on sharing information from different people in different locations to create a unified understanding of the environment for the whole group, that is then used to complete specific goals (Wise et al., 2006). Team members need to be able to communicate effectively and cooperate with one another, and leaders must coordinate actions across locations (Wise et al., 2006). Military personnel often engage in high-stakes and complex tactical DDM in time pressured environments, and whilst technology has allowed for more complex DDM across wider territory, communication and coordination of roles can become challenging to get right.

1.1.1 Communication and coordination

Effective communication is paramount for DDM (Fiore et al., 2003). Distributed teams rely on communication and coordination to develop shared situational awareness and mental models, both helping them be adaptable and make decisions. Situational awareness is a person's perception of what is happening around them (Endsley, 1995). This can be extended to the situational awareness of teams (Salmon & Plant, 2022). Mental models are the organisation of knowledge into patterns based on previous experience that allow people to plan for future states (Jones et al., 2011). Mental models are useful for decision making as drawing on memory or skills is more efficient than learning new information and skills when needed in real-time. Shared mental models extend on this by suggesting that a team can have a mental model, developed through teamwork. Sharing information is key to developing shared mental models in novel situations (Schraagen & Rasker, 2001). By aiding in effective communication, developing these tools as a team help carry out DDM.

Effective communication does not necessarily mean sharing everything. Sorensen and Stanton (2016) suggested that teams who request more information are less effective than those who request less. Explicit coordination relates to when team members make or respond to direct requests to coordinate actions. Implicit coordination relates to situations where team members anticipate the information needs of others (via shared situational awareness and mental models) and provide information or action spontaneously (Sorenson & Stanton, 2016). For example, a sports team that can move around in anticipation of team-member actions and only communicate verbally when necessary, will be able to synchronise better than the team that instructs and explains every movement and what goal these movements are all leading towards, and what information was used to come to that conclusion. Implicit coordination is characteristic of expert teaming (Swain & Mills, 2003), probably because flexible actions can be taken faster, with autonomy, and there is no unnecessary information exchanged and additional mental workload to contend with. Implicit coordination is necessary in complex, uncertain and dynamic military environments where people are absorbing lots of information under time pressure. Perhaps allocating distinct roles and presenting only task-relevant information encourages specific information sharing through implicit coordination, leading to more expert teaming. Alternatively, presenting all information to everybody and allowing for dynamic coordination between team members may lead to better performance. This could be dependent upon a range of factors such as cognitive load and time pressure.

1.1.2 Cognitive load, time pressure and heuristics

Broadly speaking, cognitive load relates to the amount of working memory drawn on to complete a task. When people allocate most of their cognitive resources to a task, this can cause an overload leading to impaired performance (e.g., Edmunds et al., 2022). Time constraints also contribute to increased cognitive load (Gonzalez, 2004, 2005b). Cognitive demands have been shown to impact the decision making process whereby people begin to rely on heuristics (e.g., Edmunds et al., 2022), and heuristic processing can lead to errors in decision making (Gigereenzer & Gaissmaier, 2011).

A review by Edmunds et al. (2022), consistently found that individual decision makers only use all available information to classify objects from a pre-determined list of options when they have time, otherwise they use a 'satisficing' heuristic (Edmunds, Harris & Osman, 2022). This heuristic states people use less than the optimal amount of information when they have reached a pre-determined level of acceptability (e.g., objects do not look quite right but are "good enough") (Simon, 1947). The threshold of acceptability also goes down when time pressure and cognitive load increases. Lamberts (1995) found that short deadlines resulted in more generalisations than when there was no deadline in a categorisation of faces task. In a DDM task, Adelman et al. (2004), similarly found that as time pressure increased, participants made decisions before reading the most important information. People also appear to be susceptible to only focussing on what confirms their initial decisions (Mathews et al., 2009); and, when information changes over time the decision makers sometimes do not notice (Edmunds et al., 2022).

External management of cognitive load is a process of designing instructions and interfaces to support cognitive capacity and optimise performance (Bannert, 2002). Essentially, the environment and tools which someone operates in and with can be designed to be human-centered and enhance natural tendencies of people that facilitates better performance. The decision making literature also suggests that the most successful communication during uncertainty occurs when cognitive effort is minimised (e.g., Andre & Cutler, 1998; Finger & Bisantz, 2002; Kirschenbaum et al., 2014). Given the increasingly complex nature of military operations (Burke et al., 2008), and the associated time pressure in these environments, the opportunity for high cognitive load and the use of heuristics is high. For distributed teams, one suggested way to improve performance could be to consider how information is presented to and between people (Liebhaber et al., 2000) so that they have less information to contend with and a more limited scope in their role.

1.1.3 The tactical picture

The ability of distributed teams to achieve a common goal is an area of interest for naval military operations. During tactical operations a task group of two or more ships could be deployed to conduct a task together. The task could be to build the maritime picture, which is a process of using sensor information to classify unknown entities in the environment (e.g., what types of ships) and then identify how their presence impacts the task-group depending on their affiliation (i.e., friend, ally, neutral/civilian, or enemy), and their behaviour. Identifying and classifying entities is an important part of an operation (Carvalho et al., 2011; Hammond, 2006), because understanding their capabilities and motives will influence subsequent decisions made by the task group. Entities could be on a mission that threatens the objectives and safety of a task-group (Finger & Bisantz, 2002; Liebhaber & Feher, 2002; Riveiro et al., 2018). Using the most valuable information is key to making the best decisions (Mishra et al., 2015), as is facilitating optimal human performance.

Building the maritime picture can be done by using sensors that are organic to each ship, and information from other ships' sensors that is shared across the task group. The benefit of using task groups can be that multiple sensors result in more and diverse information, and an extended sensor range beyond what one ship could provide. However, this benefit can only be realised with effective sharing of sensor information across multiple ships. Due to the time pressure and uncertainty of the environment in which task groups can operate, effective forms of information sharing need to be identified and evaluated.

The Tactical Picture is one important part of information sharing within task groups. The Local Tactical Picture (LTP) displays sensor information organic to a ship, whereas the Common Tactical Picture (CTP) displays the sensor information from all ships in the task group, allowing for the integration of information from organic and non-organic sensors. The tactical picture provides a means for presenting information that then facilitates sharing and decision making. Task groups often operate in degraded environments. This could include lack of data or voice communication or sensor information. In these circumstances, how teams use their information might be more important than the volume of information.

When there are multiple decision makers, how information is displayed contributes to coordination and performance (e.g., Marusich et al., 2016). The information that a decision maker needs to be aware of depends on the type of decision they are making (Edmunds et al., 2022). Information superiority is important for military operations (Alberts et al., 2000), but this does not mean that more information is always better than less (e.g., Marusich et al., 2016; Edmunds et al., 2022). Providing more information, even task relevant, has been shown to hinder performance (e.g., Hope & Hunter, 2007; Joslyn & Grounds, 2015), as has ineffective (e.g., irrelevant, bad format, wrong time) sharing between people (Cannon-Bowers et al., 1993; Gorman et al., 2006). Research has investigated the effect of information exchange in DDM but is inconclusive as to whether more information is better than less, and why (e.g., Marusich et al. 2016; Chewning & Harrell, 1990; Goldstein & Gigerenzer, 2002; Gonzalez, 2005a; Nadav-Greenberg & Joslyn, 2009; Cannon-Bowers et al., 1993; Gorman et al., 2006; Mathews et al., 2009; Edmunds et al., 2022). Understanding the benefit of a CTP in comparison to multiple LTPs may aid the design for information sharing between ships, and distributed teams more generally.

Marusich and colleagues (2016) conducted an operational experiment where participants received text-based intelligence information on the location of objects. They were tasked to move assets to a location and capture these objects. In two experiments using two-player teams, one participant was responsible for unit movement information and the other, intelligence reports. Supporting previous research (e.g., Chewning & Harrell, 1990; Goldstein & Gigerenzer, 2002; Gonzalez, 2005a; Nadav-Greenberg & Joslyn, 2009) the authors firstly found that increasing task-relevant information did not improve decision making accuracy. Secondly, the authors found that when both partners had access to the same information in the form of a CTP, this did not improve decision making and participants also spent time and energy second guessing their teammate. The authors suggested that additional information may cause a degree of cognitive overload, but they did not test for this. The study also did not include time pressure on participants which is a critical aspect to the maritime domain.

Huber and colleagues (2007) conducted a study where teams of equal size completed a task where they searched for several targets that were randomly distributed. In one condition, each participant had their own sensor portfolio that differed from others in terms of attributes such as precision and how much of the experimental area they covered. This acted essentially as an LTP. In the other condition, participants could search and find the information gathered from other participants' sensors (i.e., CTP). Participants in the CTP condition were significantly more accurate than participants in the LTP condition. This study also did not include time pressure or a measure of cognitive load.

The above research indicates that the benefit of a CTP is unclear and might depend on the task and context. It also shows that further research is needed on the effect of cognitive load in DDM. There is an operational need to apply this line of research in the maritime context. Suggestions have been made that one way to limit cognitive load could be to control the information given to decision makers (e.g., Marusich et al., 2016; Liebhaber et al., 2000; Marusich et al., 2016). Given that time pressure is a factor in the maritime context, research on DDM should also include this.

1.2 Current study

As technology improves and military operations become more complex, the amount of information that teams have to contend with will expand, and so understanding how information volume and the way that teams coordinate affects decision making is an important consideration. A CTP or multiple LTPs are two ways to influence information volume and encourage different strategies of teamwork. The focus of the current study is to investigate the benefit of a CTP for distributed decision making during a classification and identification task in a time-sensitive maritime environment, and the effect that the tactical picture has on cognitive load.

This research extends on the information sharing literature by making all information available to both participants in one condition (CTP) and limiting it to their role in another (LTP). Knowing that effective communication is paramount for DDM, the experimental conditions are designed to require participants to communicate. To the best of the researcher's knowledge, this research is new in the maritime classification and identification domain.

1.2.1 Hypotheses

Based on previous research surrounding decision making, information sharing and availability, and cognitive load, the hypotheses are:

1. Performance (accuracy, response time) will be better when all information is available to both team members through the presence of a common tactical picture.

2. Cognitive load will be higher when all information is available to both team members through the presence of a common tactical picture.

Chapter 2: Method

2.1 Ethics statement

This study was approved by the Defence Science and Technology Group (DSTG) Low Risk Ethics Panel (WCSD-03-22), and a notification (application 35918) to the University of Adelaide Human Research Ethics Secretariat and Legal and Risk Office was reviewed and accepted. All participants were provided with a DSTG Information and Consent Form (see Appendix 1) prior to participating. DSTG participants were also provided with the DSTG Guidelines for Volunteers (see Appendix 2).

2.2 Participants

The participants (N = 28) were staff from DSTG (n = 14), and students from the University of Adelaide. Some DSTG staff were aware of the concepts of distributed decision making, and classification and identification. No participants had prior training or experience in the task. To participate in the study participants had to be either DSTG staff or university students and proficient in English.

University of Adelaide Psychology students were recruited through the Research Participation System at the University of Adelaide and received one and a half course credits for participating. Further students were recruited through word of mouth. DSTG staff were recruited through in-house emailing and word of mouth. Participation was voluntary, and participants could withdraw at any time.

2.3 Design and measures

A mixed-methods approach was employed in the study. Quantitative analysis used a within-subjects repeated measures design. This allowed the performance measures to be split into different conditions of the independent variable. The independent variable was the Tactical Picture, and the conditions were LTP and CTP. The dependent variables were the performance measures Accuracy and Response Time, and Cognitive Load. Accuracy was measured based on whether the correct identification and classification decision were both made before “tracks” (i.e., ships and boats) entered a protected area that was visually located on the simulation screen. A correct classification was the result of accurately classifying a track as the correct vessel type from six images. A correct identification was the result of accurately identifying the track's behaviour based on whether it was military or non-military, its course and its speed. Response Time was measured from when the second sensor picked up a track (i.e., all required information was provided) to the time of the final decision (either the classification or identification). If no decision was made, Response Time was not included in the analysis. Cognitive Load was measured after each condition using the NASA Task Load Index (TLX) (Hart & Staveland, 1988), which provides six sub-dimensions. Qualitative data were taken in the form of survey questionnaires after each condition, to provide a broad picture of the methods employed by participants.

2.4 Materials

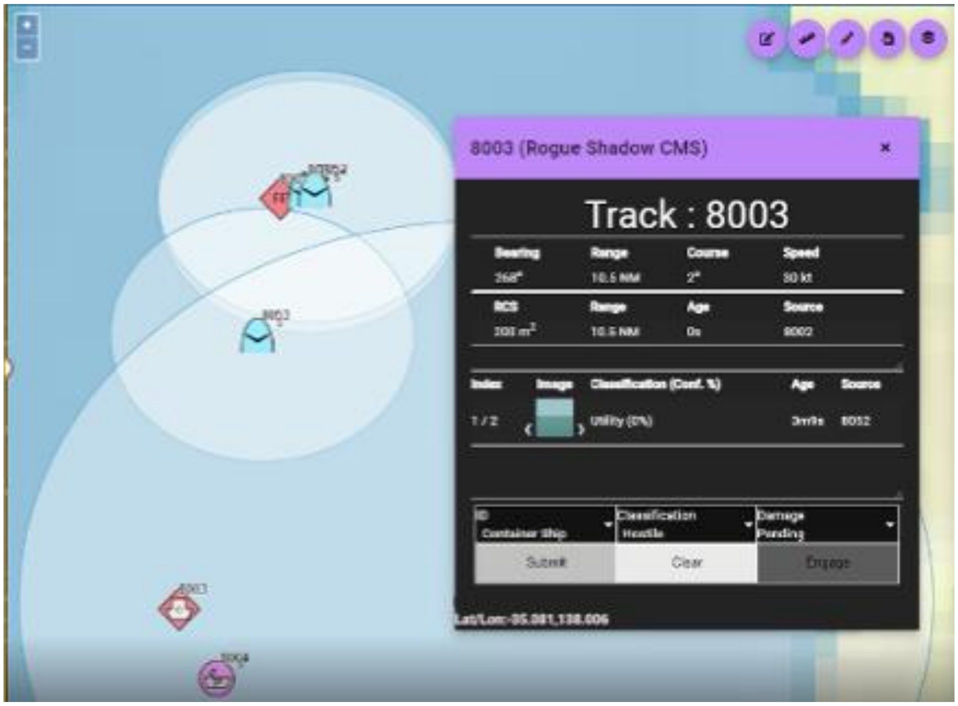
2.4.1 Experimental application

The computer-based application was created at DSTG. Simulating a birds-eye-view of the Gulf of St Vincent, three stationary ships and three stationary uninhabited aerial vehicles (UAVs) belonging to the participants' task group were displayed. Each condition was a 15-minute period where 24 pending (i.e., unclassified and unidentified) tracks would enter the simulation moving at a constant speed and direction. There were six types of vessels, and three teams they could belong to (Friendly, Neutral, Enemy). Training conditions ran for five minutes.

In the CTP condition, participants had the same simulation view. They could both see all sensor ranges and information. In the LTP condition, participants could only see the sensor ranges and information that were organic to their ship. These sensors were either a RADAR or three UAVs. Participants were "distributed" in terms of their location in the visual environment. In other words, they were virtually not co-located.

Figure 2.1

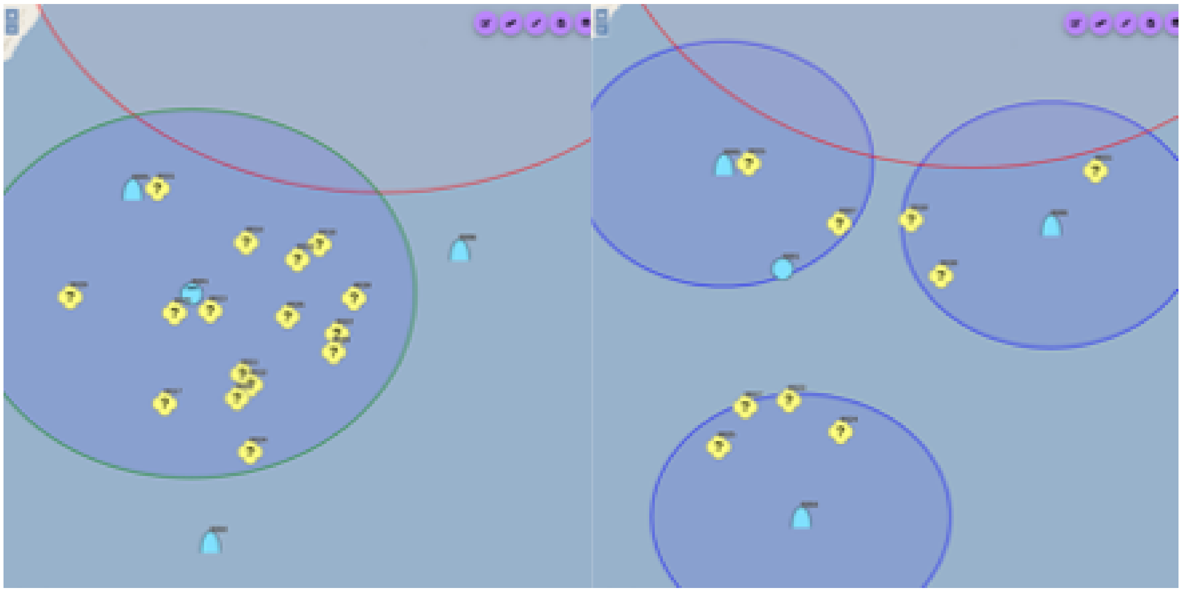
Track interface



Note: Track interface for track 8003, course and speed located top right of the track menu interface, the ID and classification decision drop-down menu is down the bottom of the interface.

Figure 2.2

Participant Screens



Note: Left side image shows the RADAR participant view. The RADAR sensor range is the green circle, and the protected area is the red circle. The RADAR participant is located on vessel that is the blue circle in the middle of the RADAR sensor range. The right side image shows the UAV participant view. The UAV sensor ranges are the three blue circles. Both images show several pending (yellow) tracks. The location of the UAV participant is off image, to the East.

Sensor ranges were designed to facilitate collaboration between the two participants in the LTP. Each UAV's sensor range radius was 4km, and the RADAR sensor range radius was 6km. The protected area had a radius of 10km, and was situated roughly 15km north of the RADAR. These radii were specifically designed to encourage active communication between participants as some tracks would only appear in both sensors for a short period of time. These sensor ranges were visually represented on the experimental screen (see *Figure 2.2)*. Unrealistic speeds of the six vessel types were used so that the simulation was easy to engage with for participants. It was important that participants were exposed to meaningful behaviour by the tracks. In a real-life scenario, vessels would be moving much slower but the task-group may have hours to make a decision rather than minutes and there would be other variables influencing performance. This experiment was designed to limit extraneous variables, allowing for the measurement of decision making performance with highly controlled dependent variables. Participants could easily see tracks moving through the gulf and use these visual cues to collaborate with their team mate and judge what to focus their attention on. Whilst operationally unrealistic, this allowed for the isolation of specific decision making characteristics that can be extrapolated out into real-world situations.

2.4.2 The software

The scenarios for the two conditions were generated by the Lead Investigator in the software program Scenario Generation and Control created by DSTG. Once the scenarios were generated, a team of software engineers at DSTG merged the scenarios with a local host environment to create a simulation "game" that allowed participants to interact in the same simulation over a localised internet connection via two computers.

2.4.3 The tracks

The design of tracks was taken from GitLab (GitLab, n.d). Four military and two non-military vessels were chosen to give participants a broad number of options to choose from. Some of the vessels chosen look similar to ensure a level of difficulty in the classification task. There were 24 tracks to identify and classify in 15 minutes. There were eight in each team type, and four military and four non-military tracks for each team. Half of the tracks were on course to the protected area, and half were travelling at "fast" speeds. A "fast" speed was defined as greater than or equal to 58 knots. To make a decision on the track, participants would click on it, and the track interface would appear (*see Figure 2.1*).

Figure 2.3

Vessel similarity examples

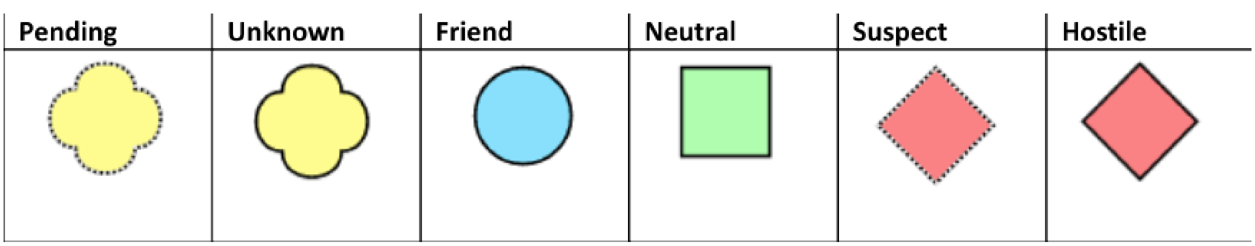
Note: Frigate (Left), Destroyer (Right). See Appendix 3 for images of all ships.

2.4.4 Symbology

Each track in the experiment was displayed as a symbol. The simulation used Department of Defense Interface Standard Joint Military Symbology (MIL-STD-2525D). This standard provides a standardised set of graphical symbols for the display of information in command and control (C2) systems. Graphical representations of objects can be readily understood faster than text alone (MIL-STD-2525D). Using a standard is important for joint operations as well as efficient collaboration in DDM. By default, all 24 tracks entered the simulation as “pending”.

Figure 2.4

Symbology



2.4.5 Decision criteria

Participants were provided with two decision criteria tables (See Appendix 3). As the aim of the experiment was to measure decision making performance, participants always had access to the tables to facilitate this. The first table included a decision matrix to aid participants in making their decision. Possible classifications were “Hostile”, “Suspect”, “Neutral” and “Friend”. The table was intentionally made difficult to navigate to increase cognitive load. The layout of the table was altered throughout piloting to identify and maintain challenging aspects of reading and understanding the table, so that these could be left in as much as possible without making the task impossible. The second table included images of the six vessels, and each symbol type (i.e., pending, unknown, hostile etc.). Participants would be able to refer to this information, combine what they see with their team mate, and make a decision.

2.5 Procedure

The experimental application was viewed on computer monitors that were back-to-back so that participants could see each other's faces but not their computer screens. Each participant was assigned a unique identification number at sign up to ensure anonymity. Participants were given the information and consent form to sign, as well as the DSTG Guidelines for Volunteers where applicable before the experiment began. Participants were either situated on the RADAR participant computer or the UAV participant computer and assigned that role. Signs saying “RADAR” and “UAV” were situated on the top of their screen as a reminder. Participants were trained on the two conditions before beginning the experiment. Each session began with training for the LTP condition. This was done intentionally to prime participants on their roles which was necessary in the LTP condition, and encourage them to approach the task similarly in the CTP condition. Ultimately, however, it was up to participants to decide how to act in each condition. Training for the LTP condition began by providing participants with a task sheet to read (see Appendix 4). The task sheets were labelled “Shared” and “Non-Shared” rather than “Common Tactical Picture” and “Local Tactical Picture” as it was assumed that this would be easier to understand for novices, and reminded them what condition they were in. The Lead Investigator referred to the conditions as “shared” and “non-shared” throughout the experiment, and explained this to mean RADAR and UAV sensor information. Once participants had read the task sheet, the Lead Investigator gave a verbal introduction to the task before starting. The training task for each condition lasted five minutes. During training, participants were encouraged to ask questions and the Lead Investigator observed them to ensure they understood the task correctly, that they understood their role (RADAR operator or UAV operator), that they knew the difference between the shared and non-shared conditions and that they could accurately differentiate between the six track types. The training tasks were designed so that participants would see each possible identification and classification, and familiarise themselves with their roles, what information they had, and what information they needed to gather from their team mate. Once the Lead Investigator and participants thought they sufficiently understood the task in the LTP condition, the same process occurred with the CTP training task. No participants needed to repeat. Both training conditions occurred before the experiment to account for order effects.

The first condition started with the participants being provided with and reading the task sheet. These task sheets (see Appendix 4) stayed with the participants to refer to during the experiment as it provided important information such as "remember that vessels disappear when they reach the end of a sensor range". Once again, this was because the primary aim of the experiment was to measure decision making performance. The order of conditions (CTP or LTP) was alternated to account for order effects. Once participants had read the task sheet, the Lead Investigator read out the following:

In the LTP condition:

"Like in the training exercise, in this scenario you do not have access to your partner's sensor information. You will have to communicate verbally to make decisions together. Your task is to correctly identify and classify each track before they enter the protected area, which is the red circle. It is critical that you make the correct decision. You both need to make the decision. Please do as much as you can in 15 minutes. You will now have 2 minutes to devise a strategy".

In the CTP condition:

"Like in the training exercise, in this scenario you will have access to both your sensor information, and your partner's. Your task is to correctly identify and classify each track before they

enter the protected area, which is the red circle. It is critical that you make the correct decision. Please do as much as you can in 15 minutes. You will now have 2 minutes to devise a strategy".

After participants had devised their strategy, the experiment began. The condition lasted for 15 minutes. Immediately after completion, the Lead Investigator provided the NASA TLX questionnaire to be filled out, and then a qualitative question relating to that condition. Both were completed by hand. The second condition began directly after this, with the exact same procedure except the task sheet and Lead Investigator introduction matched the condition.

After the CTP condition, participants were asked *"How did you work together as a team when all sensor information was available to you both? What was challenging, and what was easy?".*

After the LTP condition, participants were asked *"How did you work together as a team when you both could only see your individual sensor information? What was challenging, and what was easy?".*

After the second condition had been completed, the Lead Investigator asked participants which condition they preferred. Participants were then offered to have their results emailed to them. Each session took approximately 1.5 hours.

Chapter 3: Results

Quantitative data for Accuracy, Response Time and Cognitive Load variables were analysed to compare performance between the LTP and CTP conditions. Qualitative themes were then drawn-out following Braun and Clarke's (2006) thematic analysis method. A semantic approach (Braun & Clarke, 2006) was followed, whereby themes from two questions were identified on a surface level to give context to the quantitative data, how participants completed the task and how this relates to previous literature.

Statistical analyses (t-tests and Wilcoxon Signed-Rank tests) were run to compare the two conditions on the proportion of correct responses for Accuracy, the median Response Time, and scores on the NASA TLX. When participants had made a decision prior to receiving all information, those Response Time data were excluded from the comparisons. A caveat to the analysis is that the Accuracy and Response Time variables were analysed in pairs (as a team performance score) because the experiment was DDM in teams of two, but Cognitive Load scores were analysed individually. Power for the Accuracy and Response Time comparisons is hence lower.

3.1 Quantitative analysis

3.1.1 Accuracy and Response Time

Table 1

Accuracy and Response Time descriptive statistics

Variable	Mean	St. Dev.	Median
Proportion of Correct Decisions			
CTP	0.363	0.108	0.333
LTP	0.283	0.144	0.271
Response Time (s)			
CTP	107.286	54.925	101
LTP	176.071	105.753	138.750

Shapiro-Wilk tests for normality found that all data were likely to be normally distributed, characterised by $p > .05$. Upon analysing histograms and Q-Q plots no variables were observed to fit the normal distribution. There was a combination of skewness and randomness in the distributions for the histograms, and the quartiles in the Q-Q plot deviated from the normal distribution. Levene's test showed that the data for Accuracy were likely to have equal variance ($p = .206$) but Response Time were not ($p = .014$). After analysing box plots (visually comparing the similarity of the length of boxes) the assumption of equal variance was not met for Response Time but was for Accuracy. It is likely that the non-significant Shapiro-Wilk and Levene's results were due to the small sample size and low statistical power. Non-parametric tests were used for the analyses.

The Wilcoxon Signed Rank test revealed a significant difference in Accuracy between the CTP condition (*Mdn* = 33%), and the LTP condition (*Mdn* = 27%), $Z = -2.135$, $p = .033$, $r = 0.571$, indicating a large effect.

The Wilcoxon Signed Rank test revealed a non-significant different in Response Time between the CTP condition (*Mdn* = 101s), and the LTP condition (*Mdn* = 138.75), $Z = -1.475$, $p = .140$, $r = 0.394$, indicating a medium effect.

3.1.2 Cognitive Load

Table 2

Cognitive Load description statistics

Nasa TLX Variables	Mean	St. Dev.	Median
Mental Load			
CTP	63.390	18.005	70
LTP	65.710	18.243	65
Physical Load			
CTP	23.930	18.676	17.5
LTP	25.540	20.473	20
Temporal Load			
CTP	62.500	20.344	62.5
LTP	66.960	23.426	75
Performance			
CTP	28.390	22.610	25
LTP	34.820	24.324	30
Effort			
CTP	63.04	20.108	62.5
LTP	67.680	16.072	70
Frustration			
CTP	29.460	21.745	25
LTP	34.110	22.155	36

Note: Scores range from 0-100 where 0 indicates low workload, and 100 indicates high workload.

Shapiro-Wilk tests for normality found that Effort (CTP $p = .129$, LTP $p = .354$) and Frustration were likely to fit normal distribution. Upon analysing histograms and Q-Q plots the way previously mentioned, the Frustration data for both conditions were observed to fit the normal distribution. Effort was not. Levene's test indicated that all data were likely to have equal variance ($p > .05$). Further analysis of boxplots also suggested equal variance. Non-parametric tests were used for all comparisons were used. A paired-samples t-test was also run for Frustration given the assumptions of normality and variance were met.

The Wilcoxon Signed Rank test revealed a non-significant difference in Mental Load between the CTP condition (*Mdn* = 70), and the LTP condition (*Mdn* = 65), $Z = -0.771$, $p = .441$, $r = 0.146$, indicating a small effect.

The Wilcoxon Signed Rank test revealed a non-significant difference in Physical load between the CTP condition (*Mdn* = 17.5), and the LTP condition (*Mdn* = 20), $Z = -0.750$, $p = .453$, $r = 0.142$, indicating a small effect.

The Wilcoxon Signed Rank test revealed a non-significant difference in Temporal Load between the CTP condition (*Mdn* = 62.5), and the LTP condition (*Mdn* = 75), $Z = -1.446$, $p = .148$, $r = 0.273$, indicating a small effect.

The Wilcoxon Signed Rank test revealed a non-significant difference in Performance between the CTP condition (*Mdn* = 25), and the LTP condition (*Mdn* = 30), $Z = -1.709$, $p = .087$, $r = 0.323$, indicating a medium effect.

The Wilcoxon Signed Rank test revealed a significant difference in Effort between the CTP condition (*Mdn* = 62.5), and the LTP condition (*Mdn* = 70), $Z = -1.990$, $p = .047$, $r = 0.376$, indicating a medium effect.

The Wilcoxon Signed Rank test revealed a non-significant difference in Frustration between the CTP condition (*Mdn* = 25), and the LTP condition (*Mdn* = 36), $Z = -1.193$, $p = .233$, $r = 0.226$, indicating a small effect.

The Paired Samples t-test revealed a non-significant difference in Frustration between the CTP condition ($M = 29.460$), and the LTP condition ($M = 34.11$), $t = -1.170$, $p = .252$, $r = 0.221$, indicating a small effect.

3.2 Qualitative analysis

Themes were extracted to provide context to the quantitative analysis and to understand how the hypotheses were supported or not. Subsequent general themes relating to the conditions were also extracted.

Table 3.

Hypothesis related themes

Themes	Quote Examples (*Participant ID – Condition)*	Number of Mentions
Theme 1 (Coordination Strategies) - There were two general strategies mentioned in the CTP condition Strategy 1 - to work together one track at a time Strategy 2 - to decide on how to split up the tracks before the task and mostly work individually (with some participants asking for a double check)	"One person selected the model to look at. Both looked at images to identify. Identified it together, agreed, and then one person would submit the answer" (*3 – CTP*) "We still retained the same roles, we thought we would work better this way" *(14 – CTP)* "We decided to only discuss details when necessary and work independently for the most part. I think this helped reduce stress levels caused by delay by either participant as each person could feel more in control" *(5 – CTP)* "We decided to split the tracks based on even-odd numbers. Since there was no communication involved it was easy" *(9 – CTP)*	Strategy 1: 12 Strategy 2: 11
Theme 2 (Communication) - In the CTP condition, some participants found communication unnecessary, whereas others found it to be the reason for improved accuracy and speed	"Since there was no communication involved it was easy" *(9 – CTP)* "Assumed that the class [classification] decision was correct without review" *(11 – CTP)* "Being able to get a second opinion on all the data made confirmation much faster" *(15 – CTP)* "Relied upon communication and ensuring all information was conveyed" *(16 – CTP)* "Ability to confirm allowed for higher confidence and probably higher accuracy" *(19 –CTP)*	Communication a benefit of a CTP: 8 Communication unnecessary with a CTP: 5

Theme 3 (Information Sharing/Availability) - It appeared to be personal preference whether the availability of information or the need to share it increased or decreased cognitive load *Phrases such as "stress", "workload", "harder", "challenging", "frustrating" and "easier" were counted under the umbrella of subjective "cognitive load".*	"We decided to only discuss details when necessary and work independently for the most part. I think this helped reduce stress levels caused by delay by either participant" *(5 – CTP)* "Having more info seemed more pressing"*(14-CTP)* "Much easier to have a shared display as it does allow for us to multitask" *(15-CTP)* "Ability to dynamically share workload helped offset time demanding tasks" *(19 – CTP)* "Felt a lot easier, as I didn't feel limited by info/keeping in mind team mates info" *(30 – CTP)* "It was a bit stressful having to wait because we never knew when something would pop up" *(4 – LTP)* "Only being able to see the images I found it sort of stressful to determine what the classification was" *(6 – LTP)* "This was more fun, probably because I didn't have to check as much information" *(11 – LTP)* "Let partner look up table, I just concentrated on the images. Far less stress doing it that way" *(12 – LTP)* "The isolation of tasks helped focus and I found it easier to manage time. Overall this version was easier cognitively but the limitations of the interface were more apparent" *(19 – LTP)* "Non-shared was easier than shared as the mental load was shared (focusing on one aspect of identification)" *(20 – LTP)*	Information availability increased cognitive load (CTP): 2 Information availability decreased cognitive load (CTP): 4 Information sharing increased cognitive load (LTP): 3 Isolation of tasks decreased cognitive load (LTP): 5 Not needing to communicate decreasing cognitive load (CTP): 2

Theme 4 (Response Time) - Participants felt like they were slower in the LTP condition due to needing to share information	"Much slower pace as we had to communicate more and wait for each other to receive info" *(4 - LTP)* "Considerably more difficult as we each needed to corroborate information to properly identify the ship. … It took us considerably longer to properly classify the ships" *(16 - LTP)* "It felt like we were only effective when we could both see the ship in other words, forward planning was limited" *(30 - LTP)* "It was challenging to fill in the information fast enough so the ships wouldn't pass the radars" *(29 – LTP)* "It did free us up to allocate tasks to one another, which made things faster" *(18 – CTP)*	8

3.2.1 General themes

General comments across both conditions showed that the decision making table was difficult to navigate (five mentions). For example, "The challenge was in looking at the sheet with the tables for identification of the vessel type. The table is not very user friendly" (*9 – LTP*). Ten participants also mentioned that picking the right vessel type was challenging. In general, participants felt like they were under time pressure. Communication (38 mentions) and the presence or lack of a common tactical picture were overwhelmingly mentioned across participants but thoughts surrounding what improved performance, what hindered performance, and what influenced cognitive load all varied.

3.2.2 Comparing conditions

In general, some participants preferred the LTP condition (*n*=13) over the CTP condition (*n*=8), and the rest had no preference. The qualitative analysis supports this and provides context to why there were so many non-significant differences between conditions. Across the themes identified, it appears as though condition preference was largely individual. Also, there were aspects of the task that subjectively made some participants stressed, but were other's reasons for not feeling as stressed in that given condition (e.g., "Non-shared was easier than shared as the mental load was shared (focusing on one aspect of identification)" (*20 – LTP*), "Only being able to see the images I found it sort of stressful to determine what the classification was" (*6 – LTP*)). Different themes may have come out if roles were retained and enforced in the CTP condition. The only clear difference consistently appearing as a theme was that participants thought they were slower to make their identification and classification decisions in the LTP condition due to needing to share information (eight mentions).

Two strategies were identified in the CTP condition. These were; working together on one track at a time (12 mentions), or; splitting up the tracks before starting (11 mentions). Some teams retained their LTP condition roles thinking that this led to better workflow.

Five participants believed communication was not necessary in the CTP condition. For example, "Since there was no communication involved it was easy" (*9 – CTP*). On the other hand, 8 participants thought that the ability to cross check answers led to better performance with participant 19 stating it "allowed for higher confidence and probably higher accuracy" (*CTP*).

None of the comments from the eight participants who believed communication led to better performance in the CTP could be read as suggesting that this decreased cognitive load. However, there were two responses saying that having an individually focussed strategy in the CTP condition decreased cognitive load (i.e., no need to communicate).

Responses relating to the effect of information sharing (LTP) compared to information availability (CTP) on cognitive load do not indicate a clear consensus. Two participants thought that the large amount of information in the CTP condition increased cognitive load ("more pressing" (*14 – CTP*)), whereas three participants thought that needing to share information (i.e., communication) in the LTP condition increased cognitive load. However, four participants thought that having all the information in CTP reduced cognitive load, due to the "ability to dynamically share workload" (*19 – CTP*). And, five participants thought that only having access to half the information in the LTP reduced cognitive load because the "mental load was shared (focusing on one aspect of identification)" (*20 – LTP*). Participant 14 who thought that having more information in the CTP condition made the task "more pressing", was also part of the pair who maintained their given LTP roles.

In a strictly DDM sense, it appears that the benefit of a CTP is the ability to "dynamically share workload" (*19 – CTP*), "multitask" (*15 – CTP*) and double check answers. The disadvantages surrounded having to check more information (*11*) and that having more information seemed "more pressing" (*14*).

Chapter 4: Discussion

This study aimed to explore any performance benefits of using a CTP compared to multiple LTPs in a distributed decision making classification and identification task.

4.1 Overview of performance between LTP and CTP conditions

Performance was firstly analysed by comparing Accuracy and Response Time between the CTP and LTP conditions. Overall, Accuracy was significantly higher in the CTP condition, but Response Time was not significantly different between conditions. This partially supports the first hypothesis. The results support the notion that information display effects DDM (e.g., Marusich et al., 2016), but disagree with the suggestion that limiting information will improve performance (e.g., Hope & Hunter, 2007; Joslyn & Grounds, 2015, Marusich et al., 2016).

The findings support the notion that a common tactical picture improves accuracy for a classification and identification task (e.g., Huber et al., 2007). This could be because team members can dynamically share their workload and double check each other's work. Themes from the qualitative analysis suggest that the significant differences for the Accuracy measure are likely due to participants being able to choose a strategy that best works for them. Some participants thought that communication was beneficial in the CTP condition, whereas others indicated that working alone was better. In a strictly DDM sense, the ability to double check a team member's answer and dynamically share workload were benefits of a CTP thematically.

The finding that Response Time was not significantly different between conditions on a surface level suggests that the level of information and need to share does not influence the speed of classification and identifications. However, given that standard deviation in Response Time in the LTP condition was more than double that of the CTP condition, it is likely that the individual preferences in strategy displayed in the CTP condition masked any effect if a stricter strategy was enforced for that condition.

Participants did indicate that they felt slower to complete the task in the LTP condition and this is at least reflected in the mean and median scores. Given the above, the non-significant differences in the statistical analyses are also likely due to the small sample size and resulting lack of statistical power.

Some participants made final decisions before receiving all the required information (i.e., at least RADAR and one UAV image) in both conditions, but no mention of this as a strategy (guessing a tracks course and speed visually) were mentioned in the questionnaire responses. It is possible that participants were relying on satisficing heuristics (a likely learning effect is that a track on route to the protected area at a fast speed was visually obvious), or guessing blind due to the time pressure. The use of heuristics in DDM (e.g., Adelman et al., 2004) is unsurprising given that many Cognitive Load scores were in the high range, and that cognitive demands influence the use of heuristics (e.g., Edmunds et al., 2022).

4.2 Overview of Cognitive Load between LTP and CTP conditions

Performance was also compared by subjective Cognitive Load in both conditions. Overall, only one sub-dimension measure of Cognitive Load was significantly different between the two conditions. This was Effort, suggesting that participants had to try harder in the LTP condition. These findings do not support the second hypothesis and indicate that neither the availability of information (or lack of), nor the need to communicate (sharing information and coordinating decisions), really affects cognitive load for this particular task. External management of Cognitive Load (i.e., Bannert, 2002) through the tactical picture resulted in a significant increase in Effort when participants had less information but needed to communicate (I.e., LTP condition), contrary to the second hypothesis that additional information would have increased measures of Cognitive Load (e.g., suggestion from Marusich et al., 2016).

Given that Cognitive Load was largely stable across conditions, this does not necessarily disagree with research that has found it impacts the decision making process due to increasing the use of heuristics (e.g., Edmunds et al., 2022; Adelman et al., 2004), but it might disagree with the suggestion that selectively limiting information could decrease Cognitive Load (Liebhaber et al., 2000; Marusich et al., 2016). Given that Accuracy was higher in the CTP condition but Cognitive Load was stable across conditions, this indicates that Cognitive Load was not related to performance differences between conditions. The results only suggest that slightly more effort was required in the LTP condition.

These findings are reflected in the qualitative data. The necessity to collaborate (LTP), and the ability to work independently (CTP) were found to either make the task easier or harder depending on the participant.

Personal preference probably played a part in determining subjective cognitive load as well as this being mitigated by the ability to have more control over how the task was performed in the CTP condition. In future research it would be useful to see what would happen to Cognitive Load if researchers enforced a “double check” (also enforcing a communication mechanism) in the CTP condition.

4.3 Strengths

The design of this experiment limited extraneous variables to the best of the investigator's knowledge. The thematic analysis did not uncover any variables unforeseen by the investigators either.

Participants stated that the decision table was a difficult factor that caused stress and this is also reflected in the NASA TLX data often reporting scores in the “high range” (50-79; Hancock & Meshkati, 1988). This was a conscious decision by the investigators. The design of the experiment adequately introduced a factor that would sufficiently increase Cognitive Load. Participants also commonly stated that they felt under time pressure, contributing further to the literature by including a variable that has been missing from some studies (e.g., Marusich et al., 2016, Huber et al., 2007).

The track interface was not seen to affect performance on the task. Given the aim of this experiment it was important that participants did not feel slowed down by the process of finding information and inputting their decision choices. Furthermore, participants were able to quickly and effectively learn to use the software and perform the task.

Participants said that picking the right ship-type was challenging because some looked quite similar. Given that the images were modelled off real ships and boats, this is likely to be realistic.

All indications lead to the experiment being appropriately designed and supporting the methodology, allowing for accurate analysis of the specific variables

4.4 Implications

Theoretically, this study adds to decision making literature that is inconclusive on the effect of information overload and information sharing on DDM performance and cognitive load (e.g., Marusich et al. 2016; Chewning & Harrell, 1990; Goldstein & Gigerenzer, 2002; Gonzalez, 2005a; Nadav-Greenberg & Joslyn, 2009; Cannon-Bowers et al., 1993; Gorman et al., 2006; Mathews et al., 2009; Edmunds et al., 2022). The study shows that distributed decision making in the context of a classification and identification task is better when decision makers have a common tactical picture. The study also extends on previous DDM studies (e.g., Marusich et al., 2016) by finding that Cognitive Load may not be affected by the tactical picture when these decisions can be shared between multiple people.

The primary practical implication of this study is that there are performance benefits (i.e., higher accuracy) when using a common tactical picture in distributed decision making. Given that in a CTP there are more options at the disposal of a team for how they complete identification and classification tasks, roles can still be maintained and the benefits of sticking to specific roles can be utilised whilst also having the ability to double check decisions, and dynamically shift workload between people. Teams can more effectively strategise for optimal performance depending on the scenario they find themselves in. A third person (e.g., a supervisor) could oversee people completing classification and identification tasks and provide that dynamic shift of workload based on how people are performing and feeling.

Hanna and Richards (2018) stated that the three main types of behaviour in team decision making are leadership, individual and team enabling behaviours. Team enabling behaviours include synchronising actions, communication and team member monitoring. This feeds into what was found to be the main benefits of a common tactical picture. If maritime task groups are set up with directions being taken by supervisors, there is an opportunity for clearer communication (common information), monitoring (double-checking decisions and assessing fatigue), and the dynamic synchronisation of actions. This leads to a higher chance of expert teaming and implicit coordination. Supported by participants stating that communication can be unnecessary in CTP, one interpretation of this is actually that the CTP allows for shared situational awareness and the development of shared mental models, whereby there is higher flexibility in actions, more autonomy, and only necessary communication occurring. As previous research has suggested that ineffective sharing of information can hinder performance (Cannon-Bowers et al., 1993; Gorman et al., 2006), it is likely that using a standard CTP rather than leaving it up to individuals to provide information at any point provides appropriate balance of information availability and communication (i.e., the most effective DDM).

Given that the benefits of a CTP were found to be the ability to double check answers, and share workload, this is a good outcome from the study regardless of the quantitative analysis and highlights the benefits of a mixed-methods approach. Because accuracy was improved in the CTP condition, the perceived benefits of a CTP can still be utilised. The challenges of a CTP were more responsibility and contending with more information. In contrast, qualitative data suggested that a benefit of the LTP condition was the isolation of tasks, but that having to share information can increase cognitive load. The latter point agrees with what is known in the literature (e.g., Andre & Cutler, 1998; Finger & Bisantz, 2002; Kirschenbaum et al., 2014). Fortunately, processes could be put in place where designated roles are still enforced, but decisions can be checked easily without the necessity for communication (i.e., all the information is there for a second decision maker), and workload can also be dynamically shared between people over time through communication when necessary. With a CTP, the isolation of tasks is still possible, but the requirement to share information is not.

4.5 Limitations

This study has low power due to the small sample size. Given the differences in mean and median scores for Response Time, it is possible that the analysis missed a significant difference given that participants thought they were slower in the LTP condition. Due to time constraints with completing the project, it was not possible to recruit any more participants.

Subjective measures of Cognitive Load are not without their criticism. For example, research has found that the NASA TLX might measure perceived task difficulty rather than cognitive load, and that it is heavily reliant upon participants having the same interpretation of each construct (e.g., McKendrick & Cherry, 2018). It might be appropriate to run a similar experiment that utilises more objective measures of cognitive load such as heart rate (Paas & van Merrienboer, 1994), pupil dilation (van Gerven et al., 2004) or electroencephalography measures (Antonenko et al., 2010). Individual differences in perceptions of cognitive load, and the nature of self-reports are likely to have impacted the data.

After analysing the results and contrasting them with previous literature, what is seen as “better” for Response Time is probably too subjective, and dependent upon how speed is interpreted. Given that the study was primarily interested in making the right decision, more appropriate hypotheses might have separated Response Time from Accuracy. Speed of decision making could be interpreted in many ways in relation to accuracy. Heuristic processing and expertise are two concepts that tie into speed but can mean different things.

4.6 Suggestions for Future Research

Given the limitations of the experiment, further research is needed to understand whether a CTP resulted in higher accuracy based on more dynamic DDM, or participants being able to engage in the task in the way that suited their individual preference. This could be done by designing two conditions with a CTP, one where decisions can be inserted by either person in a pair, and the other where they have to be inserted by the pair. In doing this, the research could also further investigate the use of heuristic processing. It would also be good to attempt to alter cognitive load between two conditions where the task is the same (i.e., the CTP condition twice, one with an extra source of cognitive load). This would provide extra information as to the effect of cognitive load on performance that might have been missed in this study. It might also be useful to use a participant pool of either experts or novices to limit any effect that this could have had on the findings.

Cognitive load theory suggests that people who have expertise in a task will not be cognitively impacted by more information, but less-skilled people will (Runswick et al., 2018). Running an experiment where participants are grouped by expertise might add to this study and uncover some potential reasons as to why there was a lack of significant findings and a variation of possible reasons within the qualitative themes. This would also have further implications for the use of a CTP where there is inherently more information to look at but people engaged in the task would be experts.

4.7 Conclusion

Being able to accurately classify and identify unknown vessels in a timely manner is critical in the maritime context. The present study demonstrates that the benefits of using a common tactical picture over a local tactical picture are that it results in higher accuracy and allows for teams to dynamically share workload. This is significant because it means that the structure of teams could hypothetically be organised in such a way that allows for the development of shared situational awareness, mental models, and expert teaming, without the potential draw backs of additional cognitive load. Future research should unpack the effect of increasing cognitive load in a common tactical picture and any resulting use of heuristic processing, and compare experts to novices on the same task to understand whether this had any effect on the findings of the present study.

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Appendix 1: Information and Consent Form

INFORMATION SHEET AND CONSENT FORM

The effect of a shared tactical picture on Distributed Decision Making in a Maritime identification and classification task

Brief description of the Study.

This study is looking at how teams make decisions based on the type of information they are provided. It is being done because in the Australian Defence Force, there may be situations where decision makers do not have access to all of the information. Broadening our understanding of the human psychology behind decision making is beneficial to helping the Defence Force do the best job they can.

This study is being undertaken by the lead researcher ([redacted] to fulfil a requirement for completion of his degree. This study is a collaboration between the University of Adelaide, and the Defence Science and Technology Group (DSTG).

Your part in the Study.

Your participation in this study is entirely voluntary; you have no obligation to take part in the study, and if you choose not to participate there will be no detriment to your career or degree.

You have the right to withdraw at any time with no detriment to your career or degree.

Procedure

The experiment will take approximately 1.5 hours of your time. You will participate in a training exercise, which is a 5-minute version of the experiment where you will learn what your task is, and you can ask any questions. This training exercise can be repeated.

The experiment will be conducted on a computer screen where you and the other participant will be virtually located on two different ships. Other, unknown objects will be seen moving towards both of you. You will be seated back-to-back, and can communicate verbally.

You will be working with your experimental partner to make decisions about unknown objects. These objects need to be classified (as a type of ship) and identified (as friendly, suspect, hostile or neutral) before they enter the circular exclusion zone. It is up to the two of you to communicate what you are seeing, as you will have different roles and access to different information.

More information will be provided during training.

Risks of participating.

Participants may experience minor time pressure stress when communicating on decisions. Short breaks will be taken between scenarios.

Participants may experience minor discomfort from being seated. Participants can rest between scenarios.

Statement of Privacy.

Data will be stored virtually on a Department of Defence system. It will not be transferred from any Defence system or GovTeams (microsoft teams for Government) in raw form. Data will only appear outside defence systems in aggregated form (e.g., averages), as well as broad themes and direct quotes (non-aggregated) in reports such as the thesis paper being written that utilises this data. Anonymity will be preserved. For the raw data, participants will be given an ID number that only the lead researcher ([redacted] has access to. Each line of raw data belonging to a participant will be assigned to the ID number, not any names. These names are kept separate and are only for the purpose of correctly assigning data to the right participant. No names will be included anywhere, any names in the qualitative data will be removed and quotes will not be named. Data will not be kept for future research.

Other relevant human research ethics considerations.

The research will be monitored by the researchers only. Raw (de-identified) data may be looked at by researchers at DSTG and the University of Adelaide isted on the relevant ethics protocol, to ensure accurate data analysis is conducted. Research results will be disseminated in a research thesis, in the form of aggregated, de-identified data. Data can be withdrawn if a participant withdraws before the activity is completed. This research is funded by DSTG. There will be no payments made to participants.

If you are adversely affected by the research, you can contact:

DSTG participants – Contact the DSTG Low Risk Ethics Panel:

[redacted]@dst.defence.gov.au

University of Adelaide participants – Contact the University of Adelaide Human Research Ethics Committee:
Phone: +61 [redacted]
Email: [redacted]@adelaide.edu.au

Name the investigators.

Lead researcher, '[redacted], can be contacted on [redacted], or [redacted]@adelaide.edu.au

Should you have any complaints or concerns about the manner in which this project is conducted, please do not hesitate to contact the researchers in person.

Alternatively, you may contact the DSTG Low Risk Ethics Panel.

Chair, DSTG Low Risk Ethics Panel
Email: [redacted]@dst.defence.gov.au

CONSENT

I ______________________ give my consent to participate in the project described above on the following basis:

I have had explained to me the aims of this research project, how it will be conducted and my role in it.

I understand the risks involved as described above.

I am cooperating in this project on condition that:

- the information I provide will be kept confidential
- the information and data I provide can be used for this project and for for future studies, any new researchers will only have access to data that cannot identify me.
- the research results will be made available to me at my request and any published reports of this study will preserve my anonymity.

I understand that:

- there is no obligation to take part in this study,
- if I choose not to participate there will be no detriment to my career, degree or future health care
- I am free to withdraw at any time with no detriment to my career, degree or future health care

I have been given a copy of the information/consent sheet, signed by me and by the principal researcher (name) to keep.

I have also been given a copy of the *DST Group Guidelines for Volunteers.*

Participant

Full Name	Signature	Date

Researcher

Full Name	Signature	Date

Should you have any complaints or concerns about the manner in which this project is conducted, please do not hesitate to contact the researchers in person. Alternatively, you may contact the DST Low Risk Ethics Panel at [redacted]@dst.defence.gov.au

Appendix 2: DST Guidelines for Volunteers

DST GUIDELINES FOR VOLUNTEERS

Thank you for taking part in Defence Science and Technology (DST) Group Research. Your involvement is much appreciated. This pamphlet explains your rights as a volunteer.

DST ethics review process

* DST Group has developed an approval process for low-risk research to ensure that human research complies with the requirements of the NHMRC (2018 update) *National Statement on Ethical Conduct in Human Research* and Defence policy (Human and Animal Research Manual – HUMRESMAN 2020).
* If you are told that the project has DSTG ethics approval, this means that the Chief of Division or the DSTG Low Risk Ethics Panel has reviewed the research proposal and has agreed that the research is low-risk and is ethical. Ethical clearance through the Department of Defence and Veteran Affairs Human Research Ethics Committee (DDVA HREC) is not required for low-risk research.
* DSTG approval does not imply any obligation on commanders to order or encourage their service personnel to participate or to release troops from their usual workplace to participate. Obviously, the use of any particular personnel must have clearance from their commanders but commanders should not use DST Group approval to pressure personnel into volunteering.

Voluntary participation

* As you are a volunteer for this research project, you are under **no obligation** to participate or continue to participate. You may withdraw from the project **at any time** without detriment to your military career or to your medical care.
* At no time must you feel pressured to participate or to continue if you do not wish to do so.
* If you do not wish to continue, it would be useful to the researcher to know why, but you are under no obligation to give reasons for not wanting to continue.

Informed consent

* Before commencing the project you will have been given an information sheet which explains the project, your role in it and any risks to which you may be exposed.
* You must be sure that you understand the information given to you and that you ask the researchers about anything of which you are not sure.
* You should ensure you are satisfied that you understand the information sheet and agree to participate, and keep a copy.
* Before you participate in the project you should also have been given a consent form to sign. You must be happy that the consent form is easy to understand and spells out what you are agreeing to. If you are happy you should sign the consent form and keep an un-signed copy of the consent form.

Complaints

* If at any time during your participation in the project you are worried about how the project is being run or how you are being treated, then you should speak to the researchers.
* Alternatively, you can contact the Chair of the DSTG Low Risk Ethics Panel. Contact details are:

Chair, DSTG Low Risk Ethics Panel
Email: [redacted]@dst.defence.gov.au

Appendix 3 Decision Criteria

Flag	Hull Type	Course	Speed		**Correct Identification**
Red	**Military**	**0-32 degrees or 325-360 degrees**	**58kt and above**		**Hostile**
Red	Military	0-32 degrees or 325-360 degrees	Under 58kt		Hostile
Red	**Military**	**33-324 degrees**	**58kt and above**		**Suspect**
Red	Military	33-324 degrees	Under 58kt		Suspect
Red	**Non-Military**	**0-32 degrees or 325-360 degrees**	**58kt and above**		**Hostile**
Red	Non-Military	0-32 degrees or 325-360 degrees	Under 58kt		Suspect
Red	**Non-Military**	**33-324 degrees**	**58kt and above**		**Neutral**
Red	Non-Military	33-324 degrees	Under 58kt		Neutral
Blue	**Military**	**0-32 degrees or 325-360 degrees**	**58kt and above**		**Neutral**
Blue	Military	0-32 degrees or 325-360 degrees	Under 58kt		Friend
Blue	**Military**	**33-324 degrees**	**58kt and above**		**Neutral**
Blue	Military	33-324 degrees	Under 58kt		Friend
Blue	**Non-Military**	**0-32 degrees or 325-360 degrees**	**58kt and above**		**Suspect**
Blue	Non-Military	0-32 degrees or 325-360 degrees	Under 58kt		Suspect
Blue	**Non-Military**	**33-324 degrees**	**58kt and above**		**Neutral**
Blue	Non-Military	33-324 degrees	Under 58kt		Friend
Green	**Military**	**0-32 degrees or 325-360 degrees**	**58kt and above**		**Hostile**
Green	Military	0-32 degrees or 325-360 degrees	Under 58kt		Friend
Green	**Military**	**33-324 degrees**	**58kt and above**		**Suspect**
Green	Military	33-324 degrees	Under 58kt		Friend
Green	**Non-Military**	**0-32 degrees or 325-360 degrees**	**58kt and above**		**Hostile**
Green	Non-Military	0-32 degrees or 325-360 degrees	Under 58kt		Suspect
Green	**Non-Military**	**33-324 degrees**	**58kt and above**		**Neutral**
Green	Non-Military	33-324 degrees	Under 58kt		Neutral

Frigate: Military 	**RHIB (Rigid-Hulled Inflatable boat): Military.** 
Destroyer: Military 	**Speed Boat: Non-Military** 
LHD (Landing Helicopter Dock): Military 	**Fishing Vessel: Non-Military** 

Appendix 4: Task Sheets

RADAR participant

Training Scenario: Non-Shared Condition

You will now enter a training scenario. Your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will **ONLY** have access to your RADAR sensor information. The RADAR sensor will give you **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your ship. You will **NOT** have access to the three UAV sensors (tracks 8004, 8005, 8006) that are attached to your team-mates ship (track 8002). The UAVs will give your team-mate **IMAGES** of tracks. These sensor ranges are represented as a blue circle around each UAV.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions. You will need to combine information from both sensors by communicating verbally.

You will both need to input your decision for each track in the software.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

During the training exercise, please familiarise yourself with the task. Look at course and speed, and how to make your identification and classification decisions. You will see at least one of each ship, and flag.

UAV participant

Training Scenario: Non-Shared Condition

You will now enter a training scenario. Your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will **ONLY** have access to the three UAV sensors (tracks 8004, 8005, 8006) that are attached to your ship (track 8002). The UAV sensors will give you **IMAGES** of each track. These sensor ranges are represented as a blue circle around each UAV. You will **NOT** have access to your team-mates RADAR sensor information. The RADAR sensor will give your team-mate **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your team-mates ship.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions. You will need to combine information from both sensors by communicating verbally. Please do as much as you can in 15 minutes.

You will both need to input your response for each track, in the software.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

During the training exercise, please familiarise yourself with the task. Look at images of ships, and how to make your identification and classification decisions. You will see at least one of each ship, and flag.

RADAR participant

Training Scenario: Shared Condition

You will now enter a training scenario. Your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will have access to your RADAR sensor information. The RADAR sensor will give you **COURSE AND SPEED.** The sensor range is represented as a green circle around track 8001, which is your ship. You will also have access to your team-mates three UAVs sensor information (tracks 8004, 8005, 8006). The UAV sensors will give you **IMAGES** of each track. These sensor ranges are represented as a blue circle around each UAV.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

During the training exercise, please familiarise yourself with the task. Look at images of ships, course and speed, and how to make your identification and classification decisions. You will see at least one of each ship, and flag.

UAV participant

Training Scenario: Shared Condition

You will now enter a training scenario. Your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will have access to the three UAV sensors (tracks 8004, 8005, 8006) that are attached to your ship (track 8002). The UAV sensors will give you **IMAGES** of each track. These sensor ranges are represented as a blue circle around each UAV. You will also have access to your team-mates RADAR sensor information. The RADAR sensor will give you **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your team-mates ship.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions. Please do as much as you can in 15 minutes.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

During the training exercise, please familiarise yourself with the task. Look at images of ships, course and speed, and how to make your identification and classification decisions. You will see at least one of each ship, and flag.

RADAR participant

Scenario two: Non-Shared Condition

Like in the training scenario, your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will **ONLY** have access to your RADAR sensor information. The RADAR sensor will give you **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your ship. You will **NOT** have access to the three UAV sensors (tracks 8004, 8005, 8006) that are attached to your team-mates ship (track 8002). The UAVs will give your team-mate **IMAGES** of tracks. These sensor ranges are represented as a blue circle around each UAV.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions. You will need to combine information from both sensors by communicating verbally. Please do as much as you can in 15 minutes.

You will both need to input your response for each track, in the software.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

Your performance will be measured as a team, not individually.

UAV participant

Scenario two: Non-Shared Condition

Like in the training scenario, your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will **ONLY** have access to the three UAV sensors (tracks 8004, 8005, 8006) that are attached to your ship (track 8002). The UAV sensors will give you **IMAGES** of each track. These sensor ranges are represented as a blue circle around each UAV. You will **NOT** have access to your team-mates RADAR sensor information. The RADAR sensor will give your team-mate **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your team-mates ship.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions. You will need to combine information from both sensors by communicating verbally.

You will both need to input your response for each track, in the software.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

Your performance will be measured as a team, not individually.

RADAR participant

Scenario one: Shared Condition

Like in the training scenario, your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will have access to your RADAR sensor information. The RADAR sensor will give you **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your ship. You will also have access to your team-mates three UAV sensors information (tracks 8004, 8005, 8006). The UAV sensors will give you **IMAGES** of each track. These sensor ranges are represented as a blue circle around each UAV.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions. Please do as much as you can in 15 minutes.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as “unknown” until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

Your performance will be measured as a team, not individually. As you both have the same experimental screen, **only one participant is required to enter the identification and classification decision.**

UAV participant

Scenario one: Shared Condition

Like in the training scenario, your task is to correctly identify and classify each pending track based on the information you have. In this scenario you will have access to the three UAV sensors (tracks 8004, 8005, 8006) that are attached to your ship (track 8002). The UAV sensors will give you **IMAGES** of each track. These sensor ranges are represented as a blue circle around each UAV. You will also have access to your team-mates RADAR sensor information. The RADAR sensor will give you **COURSE AND SPEED.** This sensor range is represented as a green circle around track 8001, which is your team-mates ship.

Your task is to work together to correctly identify and classify each track before they enter the protected area, represented as a red circle towards the top of the screen.

When tracks reach the end of their sensor range, they will disappear. Keep this in mind when choosing a track to focus on.

You can consult the tables in front of you to help make your decisions.

TIPS:

- You may want to correctly classify ships using your images, but identify tracks as "unknown" until you can consult the course and speed
- The flag needed to make decisions will be seen in the images
- Track location information picked up by a RADAR is updated in real time, Track location and images picked up by a UAV is updated every 10 seconds

Your performance will be measured as a team, not individually. As you both have the same experimental screen, **only one participant is required to enter the identification and classification decision.**

Appendix 5: Journal Instructions – Journal of Cognitive Engineering and Decision Making

https://www.hfes.org/Publications/Submit-Your-Work/Journal-of-Cognitive-Engineering-and-Decision-Making-Information-for-Authors

Manuscript Preparation

Manuscripts should be prepared according to the APA Publication Manual (6th ed., 750 First St., N.E., Washington, DC 20002: 800/374-2721). Manuscripts will not be considered for publication unless they are prepared according to these instructions.

- ***Language:*** Only articles written in English will be considered.
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