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Perception of Autonomy and the Role of Experience within the Maritime Industry

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Abstract: The seafaring occupation will soon evolve as human operators transition to a more supervisory role for autonomous systems onboard. Therefore, gaining a greater understanding of the mindset that officers have towards the world of autonomy will aid the maritime industry by developing a baseline for future navigational training. This paper examines the perceptions and attitudes of 100 navigational seafaring participants of varying navigational ranks and levels of seagoing experience. The aim of the study was to identify the perceptions and self-conscious trust that current seafarers have towards automated and future autonomous systems. Participants were issued a situational judgement test comprising of three questions, allowing them to assess and respond to a hazardous scenario. The results of the study found that seafarers are receptive towards the introduction of autonomous shipping. Furthermore, the participants showed an awareness of what autonomous shipping would mean for the maritime industry. However, concerns remain about the responsibility and safety of the vessel in the event of the introduction of an unmanned vessel. Moreover, when comparing opinions and trust levels among the cohort of ranks, it was found that participants of a higher rank had a similar outlook towards autonomy to that of the less experienced groups.

Keywords: autonomous shipping; human factors; situational awareness; situational judgement; maritime human–automation relationship; digitised shipping

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1. Introduction

The digital age of shipping has begun. With the maritime industry looking to adopt revolutionary technologies such as autonomous systems, the world of shipping is set to undertake one of the most impactful changes since the introduction of the diesel engine. As the International Maritime Organization (IMO) looks to devise various methods to allow for the successful installation of autonomous technologies onboard through methods such as regulatory scoping exercises or the creation of the joint maritime autonomous surface ships (MASS) working group for the maritime safety committee (MSC); legal committee (LEG); and facilitation committee (FAL), it can be seen that the maritime industry is preparing for the eventual introduction of autonomy [1]. However, how successfully autonomy is introduced will fundamentally be defined by the relationship between human operators and navigational systems, through human–autonomous teaming (HATs) [2]. Additionally, the balance of the "human–automation relationship" may ultimately define the success of autonomous shipping.

As the maritime industry looks towards the future, it is key that challenges for human operators in coping with the revolutionary technologies are addressed. Currently, navigational officers on vessels that utilise an automated approach, through systems such as the autopilot and electronic chart display and information system (ECDIS), are susceptible to automation bias, complacency, and overreliance on the automated system. This has been documented within various recent maritime incidents, including but not limited to, the grounding of the *Priscilla*, *MV Kaami*, *Lauren Hansen*, *Ruyter*, and *Lysblink Seaways* [3–7].

Empirical research has identified a disconnect in the maritime industry within the human–automation relationship. In 2018, it was identified that when encountering a course deviation, through the fault of the vessel's autopilot, deck officer cadets struggled to recognise any problem [8]. Subsequently, in 2022 a study identified that deck officers and cadets found difficulty in recognising an automated fault in a simulated environment [9].

In 2015, the ageing profile of British maritime officers was highlighted as one of the key issues within the Maritime Growth Study [10]. Additionally, statistics have shown that over the course of the next 10–15 years, over 40% of the current merchant seafarer cohort will have reached the assumed age of retirement [11]. Subsequently, this may have an impact on how successfully autonomous systems are integrated with merchant seafarers. The social stigma that older human operators have less trust in automated technology holds relevance to this change within the maritime industry. Additionally, research from the aviation sector has shown that older pilots believe that there is too much reliance on automation within the cockpit of an aircraft [12]. Furthermore, research has also found that older pilots believe that automated systems cannot replace the need for a pilot, and that going forward, more emphasis should be placed on the pilot despite the technological advances, while younger pilots are more receptive and welcoming of automated systems [13]. Therefore, there is a need to understand the aspects of autonomous shipping from the perspective of the officer of the watch (OOW) and whether it differs between the various ranking groups of the shipping industry. Additionally, there is a self-awareness in trust towards automated systems shown within navigational OOW.

The mysteries and uncertainties surrounding autonomous shipping have led the maritime industry to act immediately by developing guidelines for MASS in varying levels ranging from level 1—Automated Process and Decision Support to level 4—Fully Autonomous Ship, with the IMO beginning to structure legislation to ensure the success of autonomy within the maritime sector.

The aim of this study was to ascertain the views, opinions, and self-awareness in trust of maritime navigational officers towards autonomous systems, with the intention to aid and develop future navigational training in preparation of MASS level 1—Automated Process and Decision Support. Specific research questions were defined:

1. Is the attitude and view of autonomy, from navigational OOW, positive?
2. Does the opinion of autonomy change among the ranking groups of the shipping industry, i.e., from cadet to master?

This was achieved by means of a survey containing sections asking about the participants' views, self-conscious trust, and situational judgement questions (SJQ). Through analysing the survey responses, it was possible to determine the knowledge level displayed by participants and ultimately develop answers to both research questions of this study.

2. Background

2.1. Autonomy and Automation in the Maritime Industry

As the maritime industry looks towards the future, 2050 has been highlighted as a monumental steppingstone for the marine sector. Over the course of the next 30 years, the maritime industry is aiming to develop legislation, digitised smart ports, and an infrastructure to routinely develop autonomous shipping with the aim of improving the environmental impact of the maritime industry [14]. However, the design of near-horizon onboard autonomous systems may be construed from current onboard automated systems, such as the electronic chart display information system (ECDIS), which already pose issues such as incorrect operation and an overreliance on the system [15]. Additionally, trust and overreliance on automated systems is not a novel concept and has been identified as a flaw of automation in research conducted prior to the turn of the millennium [16].

The human–automation relationship is key to the success of maritime autonomy. In various transportation sectors, it has been shown that, if correctly operated, automated systems have the potential to be beneficial for the human operator [17]. However, despite the benefits automation brings, an overreliance on automation can prove to be detrimental to the infrastructure implementing it. Research in the field of human–automation factors has proven to be a controversial topic, with studies in the field highlighting issues such as a degradation of situational awareness; out-of-the-loop performance; mind wandering; and overreliance [18].

In 1995, the grounding of the *Royal Majesty* occurred 10 miles from Nantucket Island; from this incident, the National Transportation Safety Board (NTSB) found that the cause of the accident was due to an overreliance on the vessel's automated systems, displayed by the OOW [19]. Due to the high profile of the incident, in 2002 research was conducted analysing the grounding of the *Royal Majesty* from the perspective of a crew member. This study identified the limitations of maritime automation as well as how to better utilise automation to improve the navigational officer's role rather than replace it. Additionally, the study highlighted that automation, if used incorrectly, does not remove human error but has the potential to exacerbate misunderstandings around the position and status of the vessel [20].

A multitude of issues currently stand in the way of a harmonious transition towards autonomous shipping. Communication problems and an integration of MASS into the regulations for Preventing Collisions at Sea (COLREGs) has already been highlighted among seafarers as an initial issue, as there is confusion and uncertainty as to how to perceive MASS-operated vessels in day-to-day shipping traffic [21]. Another common sociological issue has frequently been identified with the overall rapid increase in technological advancements [22]. This issue has also plagued the maritime industry with one study identifying that as technology increases, fundamentals of shipping knowledge and training may be overlooked in future maritime education and training regimes for seafarers [23]. Additionally, research has indicated that there is a need to improve the education and training standard among seafarers [24]. Therefore, a combination of these issues could prove to be a significant problem for autonomous shipping. Another common issue for seafarers is that they work in a real-time environment with time-based alarms and distractions. Research has shown that this issue has resulted in a considerable amount of time being wasted on their watch due to unnecessary alerts on the bridge, with participants of the study believing that nearly half of the alerts received on the bridge contribute to a distraction whilst navigating the vessel [25]. Furthermore, the non-standardisation of systems among vessels has already introduced problems with maintaining a level of safety between vessels [26]. A study has shown that 68% of participants surveyed have had experience with a variety of integrated bridge set ups. From this study, 62% of participants felt that they required more than a day to become fully familiar with the systems onboard, when comparatively, over half of the participants had stated that their company gives them less than 10 h of familiarization time before they are responsible for the safe passage of the vessel [27]. With issues such as these being highlighted from both research and maritime professionals, it is imperative that the industry listens to the voice of the operator about their issues to ensure the success of autonomous shipping.

2.2. Perception on Autonomy and Automation

Overreliance and trust are common themes for the future of shipping. Statistics have claimed that the leading cause of maritime incidents is due to human error, with an estimated 75% to 96% of maritime accidents being attributed to the human interaction [28]. However, technology is not infallible, and statistics do not highlight events where the human interaction has averted a course of disaster. Moreover, research has been conducted attempting to verify the human error figure through an extensive review of incidents, which ultimately found that the rate of maritime human error could not be validated [29]. Furthermore, it was discovered that while the human error can be attributed to the cause of an accident, most failures that occur are not a direct fault of the operator, with the cause of the human error failure being credited to the working environments, technologies, and organisational factors of the vessel [30].

A study was conducted analysing various incidents caused by human interaction, which found that most accidents occurred due to a breakdown in communication of misjudgments when navigating through pilot waters [31]. The degradation of communication has frequently been highlighted within the literature as a common theme for the cause of maritime incidents among seafarers [32,33]. Furthermore, another research study has identified the leading cause of human error failure to be the condition of the operator, with the recommendations being that the maritime industry should look to develop guidelines for crew members, onboard safety courses for officers, and guidance to develop a safer working environment onboard [33]. Developing a system that can optimise human–automation teaming will prove to be a step in the right direction. Allowing the human operator to act as a supervisor and the autonomous systems to undertake tasks will promote harmony within the human–automation relationship. However, as the level of autonomy onboard is increased, the situational awareness of the operator decreases [34].

Surveys have been proven to be an effective method to gain an understanding of the views of a pool of participants. Moreover, utilising situational judgement questions (SJQ), or vignettes, to test participants' reactions to a scenario has been found to be a favourable questioning method [35]. Research has identified that using vignettes and SJQ offers participants a realistic approach when answering the question [36]. This leads to the first research question of this study, with this question being answered through multiple sections of the survey and assessing the results as a homogenous group of participants.

2.3. Experience with Autonomy and Automation

The maritime industry can learn from the failures and successes of the aviation sector regarding safety and their experiences with the technological advances that have been introduced from automation [37]. Research into the aviation human–automation relationship has identified that as pilots get older, they become more susceptible to external stressors such as family, health, etc.; this results in an imbalance between operator and system [38]. Furthermore, it has been identified that while technology is a possible issue with the older generation, interfaces have been adapted and configured to suit all age ranges within the aviation industry [39]. Age has been identified as an important variable in the discussion of trust in automation [40]. The stigma of ageism with technology has been documented on multiple occasions from the consumers' perspective in trusting older operators with the running of a vehicle or system [41], or understanding the levels of trust displayed among age groups when using decision support aids [42]. Subsequently, a study conducted in 2005 identified that older humans have more trust and reliance on decision aids than the younger cohort [43], which was further corroborated by [44].

By gaining a greater understanding of the maritime industry by age, experience, and rank, it will then be possible to identify the views by group regarding trust and perception towards autonomy. Furthermore, by adopting the method of utilising SJQ, it would be possible to gain an understanding on whether a participant group truly understands the situation and how to deal with it accordingly. Therefore, this will satisfy the method to answer the second research question.

3. Method

3.1. Survey

The data sets were recorded and collected through the means of a survey, designed and disseminated through the "Online Surveys" platform. By utilising this software, it was possible to comply with General Data Protection Act (GDPR) legislation, as access to the response files is both encrypted and password protected. The aim of the survey was to collect demographic data and compare this across three main research areas, which can be seen in Figure 1:

- Navigational seafarers' views towards autonomy;
- Navigational seafarers' situational judgement;
- Navigational seafarers' trust in autonomy.

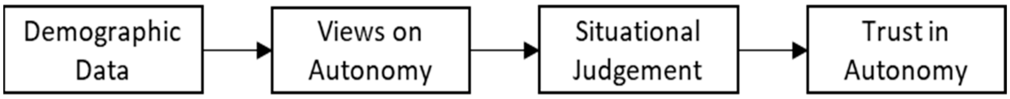


Figure 1. Survey structure.

3.1.1. Demographic Data

The aim of the "Demographic section" of the survey was to collect demographic information on each participant. Within this section, the questions that were posed to the participants were to gather the following information from each participant:

- Age;
- Nationality;
- Education History;
- Sea Time Accrued;
- Seafaring Experience.

3.1.2. Perception towards Autonomy

The "Views on Autonomy" section consisted of a 9-item questionnaire assessing the participants' views towards autonomy benefitting both crew and vessel and the self-perceived impact that autonomy will have on their respective careers. The aim of including this section was to gain a greater understanding of what the overall perception among navigational seafarers is towards autonomous operations.

The "Trust in Autonomy" section consisted of a 6-item questionnaire assessing the participants' self-perceived conscious trust towards current on-board automated systems, the implications of external factors such as fatigue or deep sea travel, and the effectiveness of alarms with respect to situational awareness. By including this section, it was possible to gain a better understanding of the maritime human–automation relationship.

For both sections, a 7-point Likert scale was used to answer the questions. The responses for items in both sections ranged from 1 = 'Strongly Disagree' to 7 = 'Strongly Agree'. All responses to the survey were anonymous, and no participant had any interaction with any of the questions prior to completing the survey. Table 1 shows the questions and answering structure for both the "Views on Autonomy" and "Trust in Autonomy" sections.

Table 1. Survey questions.

Items	Views on Autonomy
1—Aids	Autonomy and automation will aid the day-to-day operations of the vessel.
2—Unnecessary	Navigational officers do not need autonomous systems to assist their daily workload.
3—Benefit	I believe that systems such as autopilot and ECDIS are beneficial to navigational officers.
4—AHI	Throughout my time within the maritime industry, the level of automation and autonomous systems has increased.
5—AWI	As I progress throughout my career, the level of autonomy within the maritime industry will increase too.
6—Replace	Neither autonomy nor automation can replace the need for seafarers.
7—Trust	I can safely rely on and trust systems which implement autonomy and automation.
8—Supervision	Autonomy and automation can only be implemented if under the supervision of a suitably qualified person.
9—Longevity	The increasing developments in automation and autonomous systems has started to make me concerned about the longevity of my career.

Table 1. *Cont.*

Items	Trust in Autonomy
1—Trained	I trust in the automated systems which I have had training with.
2—Failure	If an incident were to occur through the fault of an automated or autonomous system, I would have less trust in the system in future. Even though the system would be under supervision.
3—Alarms	Alarms on the ship increase my situational awareness.
4—Fatigue	If I were tired or fatigued, I would be more susceptible to trust the vessel's automated systems.
5—Instincts	I would trust my instincts more than the vessel's automated systems.
6—Monotony	I could be easily distracted during night-time or watches where the vessel is at deep sea.

3.1.3. Situational Judgement

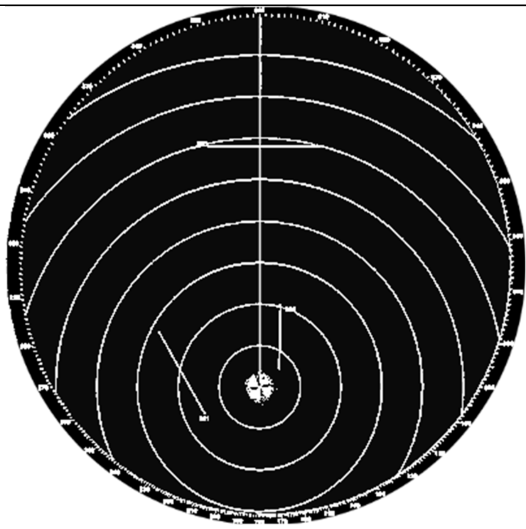
This section of the survey consisted of the participant answering three questions which gave the participant a scenario and 4 reactions. The participant was then asked to rank the responses as 1 = 'least appropriate' (Lapp), 2 = 'slightly appropriate' (Sapp), 3 = 'appropriate' (App), or 4 = 'most appropriate' (Mapp). The scenarios chosen for the assessment were derived from prior research into real-world maritime incidents.

Each of the situational judgement questions (SJQ) described a scenario that would have the participant act as the officer of the watch. From the description of each scenario, candidates would be able to gain an understanding of the vessels' position, speed, and surroundings. Additionally, within each SJQ, participants would encounter a fault that would then prompt them to analyse and rank the responses from 1 to 4.

Figure 2a–c shows the scenarios and resultant responses for the respective SJQs. The aim of SJQ1, shown in Figure 2a, was to give the participant a scenario representative of that found in a study conducted in 2021. Using a bridge watchkeeping simulator, it was found that navigational officers found difficulties in recognising an automation fault; therefore, by recreating a similar scenario, the aim of this question was to gain an understanding whether, if presented with a scenario such as the one found in Figure 2a, candidates would react appropriately by selecting a suitable response to an automation fault. Subsequently, SJQ2, shown in Figure 2b, was designed with the aim of giving the participant a mechanical fault. By designing a scenario that is a replication of a past research study scenario, it may then be possible to gain an insight into the knowledge level of seafarers, i.e., "Is there a skill gap among seafarers in being able to apply their knowledge to a real-time event or do the seafarers have a lack of knowledge regarding the situation?". The design of SJQ3, shown in Figure 2c, closely resembled the events of the grounding of the *Lauren Hansen* [5]. By reviewing the various maritime accidents, it was possible to identify various incidents where the choices that resulted in the accident occurring may be construed as the most unbelievable answer when presented in text to a participant.

SJQ1

You are in the middle of a late afternoon watch as the sole crew member in the wheelhouse. Your vessel is a 350 m container vessel travelling on a course heading of 087 at 19 knots, through autopilot navigation. Additionally, the vessel is approximately 500 nautical miles from land. Following a radar check you acknowledge that there are no traffic vessels within a 50-mile proximity of your own vessel. As you prepare to complete mandatory routine paperwork, in preparation of arriving at the next port, you hear a methodical ticking in the background coming from an unknown location within the wheelhouse *. Upon further inspection you notice that the sound is emanating from the vessel's magnetic compass. Following this realisation, you check the radar plots and find that the vessel's position has not been altered.

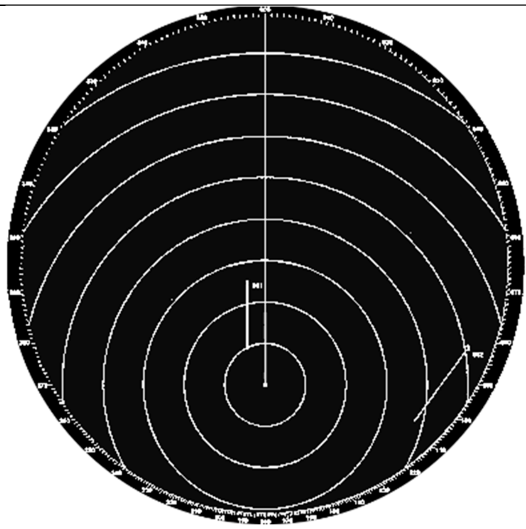


R1	Record the fault into the vessel's logbook and continue with paperwork, due to the vessel's relatively safe position, and inform the relieving officer of the fault at the watch handover.
R2	Call the captain of the vessel to inform them of the situation and ask for a lookout to concentrate on the position of the vessel whilst you complete your paperwork.
R3	Disregard the paperwork, remove navigational control from autopilot to manual and continue with the rest of the watch at the helm of the vessel.
R4	Assess the situation and check the backup gyro to ensure that the vessel's position is not wandering from a gyro drift, call for an electrician to come and assess the situation and fault whilst you continue with your paperwork.

(**a**)

SJQ2

Your vessel is a 215 m bulk carrier, travelling on a course heading of 000 at a speed of 14 knots, through autopilot navigation. Additionally, the vessel is approximately 280 nautical miles from land. At approximately 2 h into the watch, following a radar check, you acknowledge that there are 2 vessels within a 24-mile proximity ** of your vessel. From the radar plots, the first vessel appears to be 14 nautical miles on a bearing of 245, travelling at 12 knots with a heading of 345. The second vessel appears to be 6 nautical miles on a bearing of 180, travelling at 19 knots with a heading of 070. After checking the radar, you notice that the positions of the traffic vessels, through the window, do not seem to correlate with the relative positions on the radar display. Upon realising this you notice that the position of the vessel from the vessel's ECDIS corresponds to the radar display too.



R1	Contact the captain of the vessel to alert them of the situation and take manual control of the vessel until relieved.
R2	Carefully monitor the fault, through means of the watchkeeping log, magnetic compass, navigational systems, and display, and alert relieving Officer of the Watch at the watch handover.
R3	Contact ECR to inform them about the situation unfolding and begin vessel's emergency slowdown procedure.
R4	Ensure that the autopilot control is fully operational and assume that the error is from your own judgement due to fatigue.

(**b**)

Figure 2. *Cont.*

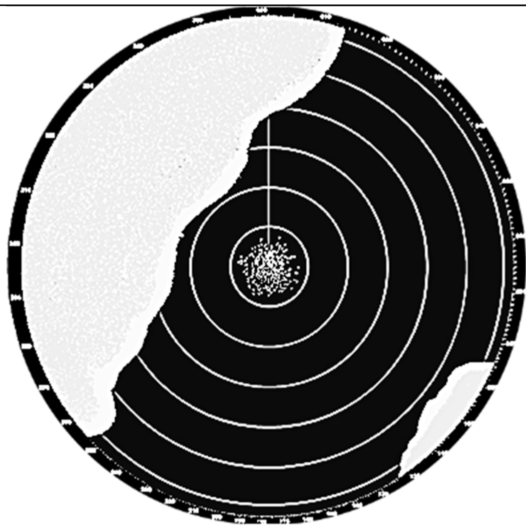
<table>
<tr><td colspan="2">SJQ3
Your vessel is a 95 m cargo vessel travelling on a course heading of 042 at a speed of 9.2 knots. Additionally, the vessel is 2 nautical miles from land to the north of the vessel's position. Your vessel has a planned course alteration position which will put the vessel 0.9 nautical miles from the same body of land. Following a radar check you acknowledge that there are no traffic vessels within a 24-mile proximity from your own vessel. During your watch, you realise that the vessel has made a sudden and unexpected turn to port, without an alarm or indication, as shown on the radar. As the vessel is now swiftly approaching the shallow waters near land, you attempt to contact the captain, who does not respond.</td><td></td></tr>
<tr><td>R1</td><td colspan="2">Conduct an emergency engine slowdown and adjust the autopilot to starboard, with the aim of bringing the vessel away from the shoreline.</td></tr>
<tr><td>R2</td><td colspan="2">Slowdown the main engine, leave the bridge in an attempt to alert the captain to the situation.</td></tr>
<tr><td>R3</td><td colspan="2">Turn steering control to manual and turn the vessel to hard starboard to avoid the shallow waters.</td></tr>
<tr><td>R4</td><td colspan="2">Slow the main engine down and bring the engine to full astern to reduce the forward momentum of the vessel. Additionally, use the vessel's thrusters to aid course correction.</td></tr>
<tr><td></td><td colspan="2">(c)</td></tr>
</table>

Figure 2. Situational Judgement Questions: (**a**) Question 1; (**b**) Question 2; (**c**) Question 3. * It should be noted that certain magnetic compass systems designed by manufacturers such as Kongsberg emit a ticking sound to indicate that the vessel is turning. This should not be confused with an alarm, as the ticking will occur during normal operations; ** The radar of the vessel was constructed to replicate the X-band (10GHz) radar system which would give the OOW a clearer indication of their surroundings.

3.2. Participant Pool and Distribution

The nature of the participant selection process allowed for a wide variety of candidates to take part in the study. Participants taking part in the study had to satisfy the following criteria:

All participants must be aged 18 or over;

All participants must have pursued a career as a navigational seafarer either as:

Navigational officer, any rank;

Navigational officer cadet;

Deck ratings crew person.

By ensuring that the criteria were satisfied, it was presumed that participants would have the knowledge and understanding to successfully complete the survey.

The survey was delivered to the participants by contacting maritime colleges within the United Kingdom. By contacting the institutions, it was possible to ensure that the survey responses were varied in the demographic data of participants, as each facility offers a wide variety of courses for both home and overseas students, in addition to non-qualified and qualified officers.

3.3. Data Collation and Analysis

Upon receipt of the survey, participants were asked to read the cover letter highlighting the aim and anonymity of the survey which allowed participants to answer truthfully, the expectations of the participant and the approximate time that the survey would take to complete. Once the cover letter had been read, the next page of the survey would offer the participant an electronic acceptance to continue with the survey. The electronic acceptance of the survey guaranteed the confidentiality of the participant's data; however, no data collected could identify a participant. The survey was disseminated to maritime educational facilities where it was then forwarded to past and present navigational officer students. The survey response was then closed once 100 navigational seafarers had participated in the survey and had submitted their responses.

3.4. Data Analysis Methods

Following the data collection stage of the study, various data analysis options were assessed. To analyse the data of this study, three methods were selected:

- Pearson's correlation test and multiple regression analysis for the "Demographic Data" section of the survey;
- ANOVA testing for the "Trust in Autonomy" and "Views on Autonomy" sections of the survey;
- Simple statistical analysis of the participant response rate for the "Situational Judgement" section of the study.

Due to the variation in demographic groups, multiple statistical comparison tests were considered. The wide variation of participants eliminated the possibility of conducting simple *t*-tests. By conducting multiple one-way ANOVA tests on the "Trust in Autonomy" and "Views on Autonomy" sections of the survey, it was possible to establish the variation in responses that participants had when questioned about a certain item. The ANOVA tests allowed for a mean and standard deviation to be calculated for each group of participants while assessing if there were any statistically significant results identified between the groups for each question posed. Subsequently, conducting a Tukey's Honest Significance Test (HSD) on the ANOVA results would identify specific groups within the demographic groups that differed from each other. Moreover, the use of the Tukey's HSD test allows for a greater chance of recognising statistically significant differences in comparison to other post hoc tests.

As the Situational Judgement section of the survey was conducted using an answer-ranking method, the analysis of the questions proved to be complex. In addition to addressing the cohort of participants as a single homogenous group, by gathering the participants into their respective groups it was possible to analyse the response rate by specific sub-groups to assess if there was an impact on knowledge and understanding. Moreover, by including a situational judgement section in the survey, it was then possible to understand if seafarers can understand the procedure of how to diagnose certain faults via a test as opposed to a real-life event or simulation.

4. Results

Statistical analysis such as Pearson's correlations coefficient and ANOVA testing were performed using the IBM SPSS Statistics 27 software (version 27, IBM, New York, USA).

4.1. Demographics

Table 2 shows the number of participants under each demographic variable. Over half of the participants of the survey were aged 34 or older and 70% of participants were fully qualified officers of the watch. Less than half of the participants had undertaken university education. The male–female split was a 91:8 ratio with one participant opting not to answer. Additionally, the nationality of participants comprised 63% British, 15% European, and 22% Rest of World.

Table 2. Participant demographics.

Variable	Categories	*n*	Variable	Categories	*n*
Education Level	College (Certificate)	16	Age	18–25 years old	27
	College (Diploma)	24		26–33 years old	20
	High School	14		34–41 years old	14
	University (Postgraduate)	20		42–61 years old	20
	University (Undergraduate)	26		Over 61 years old	19
Rank	Unqualified Officer [Inexperienced ***]	14	Sea Time	0–1 Year	19
				1–2 Years	7
	Unqualified Officer [Experienced]	13		2–5 Years	23
	Junior Officers	24		5–10 Years	13
	Senior Officers	14		10–15 Years	12
	Masters [Inexperienced ***]	19		15–20 Years	10
	Master [Experienced]	16		Over 20 Years	16

*** Participants denoted by the inexperienced tag indicate that the participant has accrued 6 months or less at their respective rank.

When assessing all four variables, it was expected that the four demographic variables would be interlinked, i.e., higher age, sea time, and education level would be associated with an increase in participants' rank. Rather than subsequent analyses being conducted with all four demographic variables, confirming this assumption would justify the use of one representative demographic variable. To confirm this assumption, a Pearson's correlation test was conducted and it is presented in the matrix in Table 3. From this matrix, it can be seen that the age, sea time education level, and rank variables are positively correlated in a strong linear correlation due to the critical value of the Pearson's correlation with 100 degrees of freedom at $p < 0.01 = 0.253979$. With all variables showing a correlation among each other, the scores of the correlation were considered. The rank variable recorded the highest correlation scores with the other variables. Therefore, when analysing the data for trust in autonomy, views on autonomy, and situational judgement, the rank of participants was taken forward as the representative demographic variable and further analysed through ANOVA testing.

Table 3. Pearson's Correlation Values.

Variable	Age	Education Level	Sea Time	Rank
Age	1	0.367 **	0.831 **	0.696 **
Education Level		1	0.391 **	0.487 **
Sea Time			1	0.758 **
Rank				1

** $p < 0.01$.

To further assess the strength of correlation of the participants' rank with other demographic variables, a multiple regression analysis was conducted to predict the participants' rank depending on the participants' "Age Group", "Educational Level", and "Sea Time" as independent variables. By running a multiple regression analysis, it was found that these variables statistically significantly predicated the rank of the participant, F (3,96) = 44.576,

p = < 0.001, R^2 = 0.582. However, the results of the regression identified that the "Age Group" of the participant did not add any statistical significance p = 0.05. The results of the regression are shown in Table 4.

Table 4. Multiple Regression using Rank as the Dependent Variable.

Model Summary							
Model	**R**		**R^2**		**Adjusted R^2**		**STD. Error**
1	0.763		0.582		0.569		0.517
ANOVA							
Model	Sum of Squares		df	Mean Square		F	Sig
Regression	35.719		3	11.906		44.576	<0.001
Residual	25.641		96	0.267			
Total	61.360		99				
Coefficients							
	Unstandardised Coefficients		Standardised Coefficients			95% Conf Int for B	
Model	B	STD. Error	Beta	t	Sig	Lower Bound	Upper Bound
(Constant)	0.556	0.154		3.622	<0.001	0.251	0.861
Age Group	0.095	0.060	0.183	1.580	0.117	−0.024	0.215
Qualification Level	0.121	0.043	0.204	2.827	0.006	0.036	0.206
Sea Time	0.345	0.081	0.500	4.284	<0.001	0.185	0.505

To categorise the participants for One-Way ANOVA testing, the following ranking groups were constructed:

- Unqualified Officers (UQ)—consisting of participants from Unqualified Officer [Inexperienced] and Unqualified Officer [Experienced], n = 27;
- Officers of the Watch (OOW)—consisting of participants from Junior Officers and Senior Officers, n = 38;
- Master (Mst)—consisting of participants from Masters [Inexperienced] and Masters [Experienced], n = 35.

4.2. Views on Autonomy

Table 5 shows the variation of scores in the "Views on Autonomy" section. The participants, while in favour of vessels employing more autonomous operations, expressed their concerns regarding the impact that autonomy will have towards their careers and that autonomy should not replace seafarers. Additionally, participants were hesitant to show complete trust and reliance in autonomy, as over 65% of participants answered item 7 with a score of 3, 4, or 5. All participant responses towards items 2, 6, and 9 were inversely scored, i.e., 1 = "Strongly Agree"–7 = "Strongly Disagree". This was conducted due to items 2, 6, and 9 being of a negative representation of autonomy on ships.

Table 5. Participant responses to "Views on Autonomy".

Item	Score	*n*	Item	Score	*n*	Item	Score	*n*
Aids	Strongly Disagree	1	Unnecessary *	Strongly Disagree	6	Benefit	Strongly Disagree	1
	Disagree	2		Disagree	8		Disagree	0
	Slightly Disagree	3		Slightly Disagree	7		Slightly Disagree	0
	Undecided	10		Undecided	15		Undecided	0
	Slightly Agree	27		Slightly Agree	23		Slightly Agree	6
	Agree	44		Agree	24		Agree	41
	Strongly Agree	13		Strongly Agree	17		Strongly Agree	52
AHI	Strongly Disagree	1	AWI	Strongly Disagree	0	Replace *	Strongly Disagree	51
	Disagree	1		Disagree	1		Disagree	18
	Slightly Disagree	4		Slightly Disagree	1		Slightly Disagree	11
	Undecided	11		Undecided	1		Undecided	7
	Slightly Agree	9		Slightly Agree	8		Slightly Agree	7
	Agree	30		Agree	40		Agree	4
	Strongly Agree	44		Strongly Agree	49		Strongly Agree	2
Trust	Strongly Disagree	10	Supervision	Strongly Disagree	1	Longevity *	Strongly Disagree	17
	Disagree	11		Disagree	3		Disagree	21
	Slightly Disagree	25		Slightly Disagree	0		Slightly Disagree	20
	Undecided	18		Undecided	2		Undecided	9
	Slightly Agree	24		Slightly Agree	13		Slightly Agree	9
	Agree	10		Agree	31		Agree	14
	Strongly Agree	2		Strongly Agree	50		Strongly Agree	10

* Items that were inversely scored.

The "Views in Autonomy" section was analysed by using nine 1×3 ANOVA tests. As shown in Table 6, for the majority of results there were no statistically significant responses ($p > 0.05$). However, for the statement "*Throughout my time within the maritime industry the level of automation and autonomous systems has increased*", it was found that there were variations between the responses of the groups. Additionally, Table 6 presents the variation in mean and standard deviation scores between the ranking groups of the participants. Using a Tukey's HSD post hoc test, it was found that officers within the higher-ranking groups disagreed with lower-ranking groups. As seen in Table 6, the OOW and Mst groups agreed with the statement, with a mean score of 6.13 and 6.54, respectively, whereas the UQ group was more undecided on this matter, with a mean score of 4.81.

Table 6. ANOVA testing for "Views on Autonomy".

Item	Mean (SD)				F	Post Hocs
	Total	UQ	OOW	Mst		
1. Aids	5.44 (1.157)	5.59 (1.047)	5.39 (1.079)	5.37 (1.330)	0.321	-
2. Unnecessary	4.81 (1.739)	4.63 (1.621)	5.11 (1.673)	4.63 (1.896)	0.881	-
3. Benefit	6.41 (1.167)	6.15 (0.683)	6.42 (0.553)	6.6 (0.818)	2.399	-
4. AHI	5.92 (1.323)	4.81 (1.52)	6.13 (1.212)	6.54 (0.561)	18.709 *	OOW > UO Mst > UO
5. AWI	6.32 (0.875)	6.15 (1.064)	6.39 (0.823)	6.37 (0.770)	0.716	-
6. Replace	2.21 (1.629)	2.04 (1.506)	2.39 (1.733)	2.14 (1.63)	0.421	-
7. Trust	3.73 (1.536)	3.81 (1.57)	3.82 (1.608)	3.57 (1.461)	0.283	-
8. Supervision	6.16 (1.195)	5.81 (1.545)	6.42 (0.758)	6.14 (1.24)	2.080	-
9. Longevity	3.54 (1.987)	3.67 (2.148)	3.37 (1.866)	3.63 (2.030)	0.228	-

* $p < 0.05$.

4.3. Trust in Autonomy

The next section of the survey to be analysed allowed for a greater understanding of the participants' conscious level of trust in autonomy. As a general consensus, trust in autonomy differed depending how the question was delivered. As shown in Table 7, participants agreed that alarms increase their levels of situational awareness, and if they receive training with the system, then they were in favour of trusting it. However, when questioned on their levels of trust following a failure, despite the system being under supervision, participants were less in favour of autonomy. Furthermore, participants disagreed with the sentiment that they may be susceptible to bias and complacency when fatigued or undertaking night-time and deep sea watches.

Table 7. Participant responses for "Trust in Autonomy".

Item	Score	Frequencies	Item	Score	Frequencies
Trained	Strongly Disagree	2	Fatigue	Strongly Disagree	13
	Disagree	3		Disagree	25
	Slightly Disagree	9		Slightly Disagree	19
	Undecided	6		Undecided	17
	Slightly Agree	33		Slightly Agree	11
	Agree	42		Agree	10
	Strongly Agree	5		Strongly Agree	5
Failure	Strongly Disagree	9	Instincts	Strongly Disagree	18
	Disagree	40		Disagree	25
	Slightly Disagree	14		Slightly Disagree	18
	Undecided	14		Undecided	19
	Slightly Agree	12		Slightly Agree	15
	Agree	5		Agree	3
	Strongly Agree	6		Strongly Agree	2

Table 7. *Cont.*

Item	Score	Frequencies	Item	Score	Frequencies
Alarm	Strongly Disagree	3	Monotony	Strongly Disagree	4
	Disagree	12		Disagree	14
	Slightly Disagree	7		Slightly Disagree	15
	Undecided	6		Undecided	13
	Slightly Agree	27		Slightly Agree	17
	Agree	32		Agree	23
	Strongly Agree	13		Strongly Agree	14

To analyse the "Trust in Autonomy" section of the survey, 1x3 ANOVA tests were conducted for the ranking groups of participants, as shown in Table 8. When analysing the participants by rank, it was found that there were differences between the ranking groups for item 3. Using a Tukey's HSD post hoc test, it was found that the differences between higher-ranking groups' response to the statement "*alarms benefit situational awareness*" differed in comparison to the lower-ranking groups. This can be seen in Table 8 with both the mean and standard deviation for all groups. Moreover, the means of each group show that participants of the UQ group agreed with the statement, with a mean score of 6.07, whereas the OOW and Mst groups were closer to being undecided, with mean scores of 4.37 and 4.57, respectively.

Table 8. ANOVA testing for "Trust in Autonomy".

Item	Mean (SD)				F	Post Hocs
	Total	UQ	OOW	Mst		
1. Trained	5.11 (1.276)	5.41 (.888)	4.92 (1.583)	5.09 (1.147)	1.156	-
2. Failure	3.19 (1.668)	3.26 (1.678)	2.95 (1.659)	3.40 (1.684)	0.699	-
3. Alarm	4.90 (1.661)	6.07 (0.781)	4.37 (1.634)	4.57 (1.770)	11.340 *	OOW > UO Mst > UO
4. Fatigue	3.38 (1.722)	3.26 (1.789)	3.16 (1.685)	3.71 (1.708)	1.043	-
5. Instincts	3.05 (1.540)	2.85 (1.379)	3.00 (1.542)	3.26 (1.669)	0.555	-
6. Monotony	4.50 (1.789)	4.37 (1.690)	4.63 (1.777)	4.46 (1.915)	0.181	-

* $p < 0.05$.

4.4. Situational Judgement

For the data analysis, the responses were rearranged following the completion of the survey, to show the responses that participants deemed "Most Appropriate" to "Least Appropriate". The SJQ and R number correlates directly with Figure 2 as shown in the Method section.

As shown in Figure 3, the consensus among the participants was that R4 ("Assess the situation . . . ") would be the least appropriate response. However, R1, R2, and R3 showed a greater disparity, despite R1 being the popular choice for most appropriate response. When analysing the responses based on rank, it can be seen that for participants of Master level the commonly selected choices for "Most Appropriate" and "Least Appropriate" were R1 and R4, respectively. Whereas the OOW group favoured R2 as the "Most Appropriate" response and R4 again as the "Least Appropriate" response. Conversely the unqualified officers group favoured R1 as the "Most Appropriate" response and R3 as the "Least Appropriate".

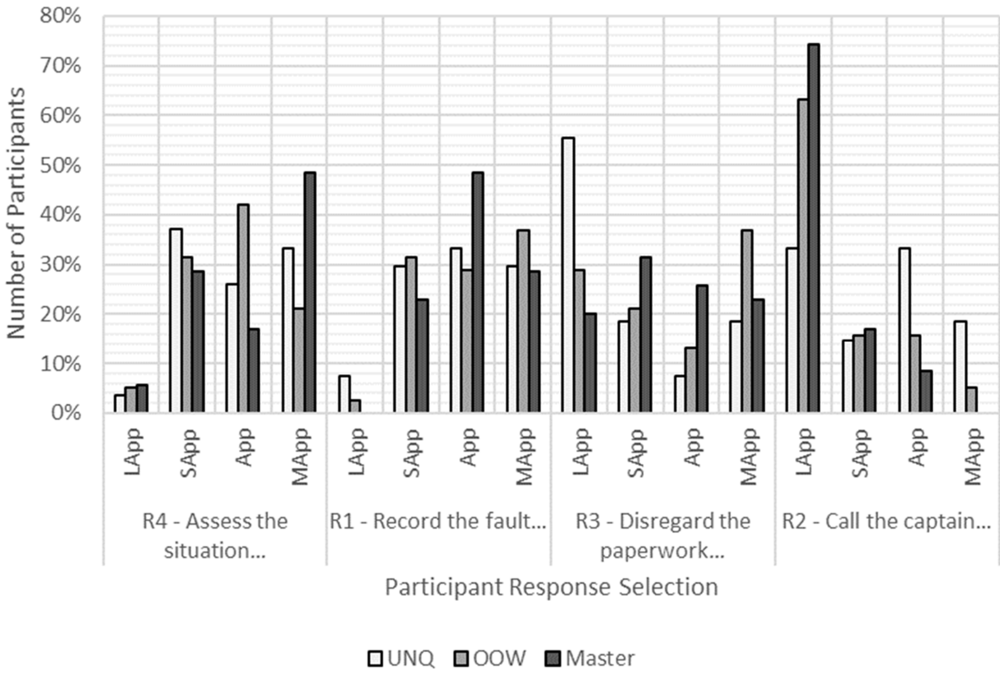


Figure 3. SJQ1 responses.

Figure 4 shows the overall response percentages of candidates for SJQ2. From this graph, it can be seen that, overall, the candidates favoured R1 for the "Most Appropriate" response and R4 was the most selected response for "Least Appropriate". When analysing the responses based on the participants' rank, this again followed the same pattern with all ranking groups selecting R1 and R4 as the "Most Appropriate" and "Least Appropriate" responses, respectively.

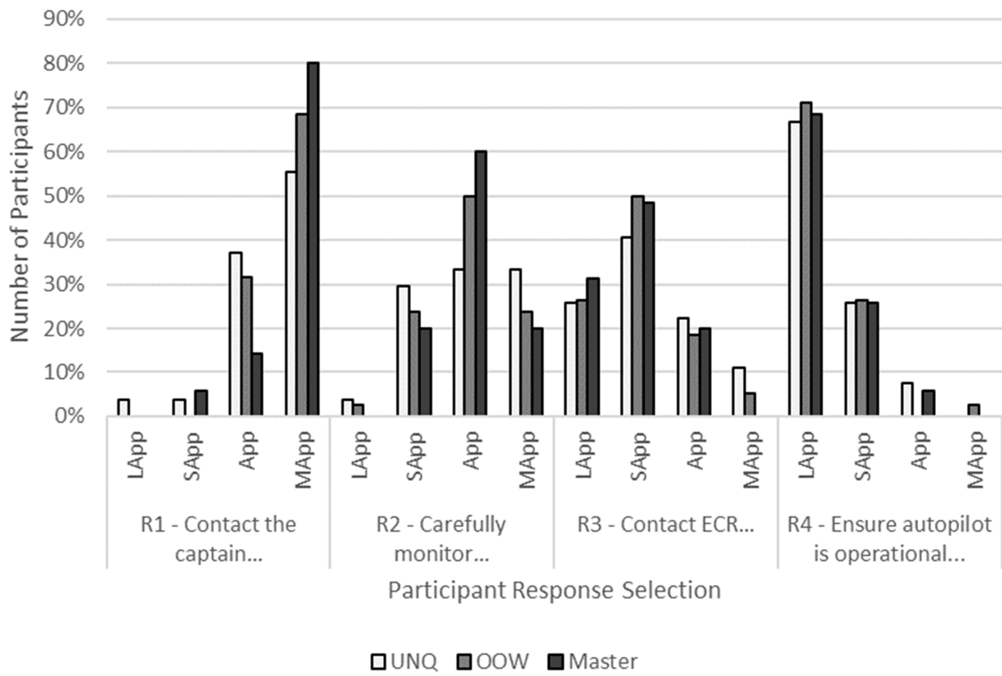


Figure 4. SJQ2 responses.

As shown in Figure 5, the overall response percentages for participants show that the majority of participants selected R1 as the "Most Appropriate" response with a selection rate of 67%, whereas the most commonly selected response for "Least Appropriate" was R4, with a selection rate of 84%. Upon further analysis of the participants' ranking groups, all groups followed the same pattern with R1 and R4 being the most selected responses for "Most Appropriate" and "Least Appropriate", respectively.

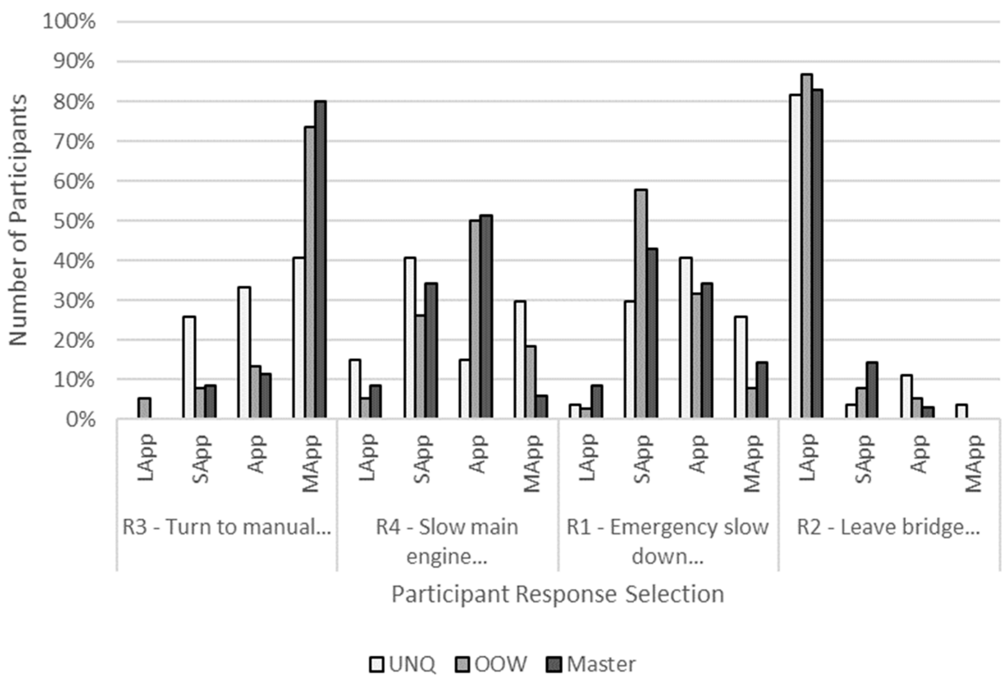


Figure 5. SJQ3 responses.

5. Discussion

5.1. Perception among OOW

The consensus view towards autonomy was generally favourable among the participants of the survey. When analysing the group for the "Views on Autonomy" section, it was identified that participants tended to agree that autonomy and automation can aid vessel operations and benefit human operators. Furthermore, participants tended to view automated systems as a necessity to navigation in assisting the OOW with their daily duties. However, participants tended to believe that a vessel should not solely rely on autonomy as the primary source of navigation, thus negating the need for the OOW, and that systems implementing autonomy should only be used under supervision. Moreover, when questioned about the levels of conscious trust that participants would place in an autonomous system, the results were far more varied, with 46 and 36 participants disagreeing and agreeing with the sentiment, respectively. This offers an interesting viewpoint that, while officers are excited about and welcoming of autonomy, they do view it as a tool that should be used to benefit the OOW and not to surpass or remove the OOW. Fundamentally, the participants believed that the overall responsibility and final decisions for the control of the vessel should be made by the human operator.

Regarding the "Trust in Autonomy" section, participants were more varied in their responses to the questions. Participants were mostly in agreement that, if trained in how to use a system, they would show trust in the system, and most participants believed that alarms enhanced their situational awareness. Additionally, participants were mostly in agreement that if a fault were to occur with the system, their trust would not be swayed providing that the system is under supervision in the future. However, participants were less inclined to agree that, if fatigued, they would trust the system more and were varied in their responses for the situation when on an eventless or night watch, that they would easily be distracted.

By analysing the SJQ section, it was possible to understand the knowledge level that participants have in fault recognition and safety procedures. For SJQ1, participants believed that the requirement of a lookout was unnecessary, by identifying R2—"*Call the captain of the vessel to inform them of the situation and ask for a lookout to concentrate on the position of the vessel whilst you complete your paperwork*" as the "Least Appropriate" response, whereas participants' choices varied among the other three response selections for "Most Appropriate", "Appropriate", and "Slightly Appropriate". SJQ1 delivered the highest variation in responses, as SJQ2 and SJQ3 had definitive response selections for "Most Appropriate" to "Least Appropriate". SJQ1 was constructed to resemble the design of the simulator exercise in a physical study previously conducted [9]. Unlike the simulator exercise, the participants were able to identify appropriate responses in the event of an automated gyro drift fault. Consequently, by issuing the participants with a text-based scenario and response, this may have proved that participants can recognise an appropriate answer if they are given choices rather than independently solving the fault.

Regarding SJQ2, participants identified R1—"*Contact the captain of the vessel to alert them of the situation and take manual control of the vessel until relieved*" as the "Most Appropriate" and R4—"*Ensure that the autopilot control is fully operational and assume that the error is from your own judgement due to fatigue*" as the "Least Appropriate" responses. This indicates that the participants are less likely to be satisfied with making assumptions on the equipment and are likely to investigate the fault further. Moreover, participants have opted to remove the responsibility from themselves by alerting the captain to the fault. SJQ2 was constructed to resemble the design of the simulator exercise in a physical study previously conducted [45]. By introducing a mechanical fault into the text-based scenario, participants were able to identify the appropriate response, which resembled the decisions made within the simulator study.

For SJQ3, the participants selected R3—"*Turn steering control to manual and turn the vessel to hard starboard to avoid the shallow waters*" as the "Most Appropriate" and R2—"*Slowdown the main engine, leave the bridge in an attempt to alert the captain to the situation*" as the "Least Appropriate" responses. Both selections highlight that in the event of imminent threat, the participants are likely to undertake manual control of the vessel to attempt to remove the vessel from impending danger. SJQ3 was constructed to resemble the design of the events that occurred during the grounding of the landing craft *Lauren Hansen* [5]. The results of SJQ3 contradict the events that occurred during the incident. The grounding of the vessel occurred due to the OOW opting to leave the bridge to find the captain, whereas the participants identified that response as the "Least Appropriate" action to take.

By extrapolating the findings of the SJQ section of the survey, it is possible to assume that there is not a knowledge gap among the majority of navigational seafarers. However, there is a disparity in applying their knowledge as shown by the findings of both real-world incidents [21] and simulated research studies [9]. Moreover, it is probable that real-world stressors such as distractions and a degradation of communication can negatively influence the application of knowledge [30,31], which do not have an impact on the findings of this study.

5.2. Experience with Autonomy and Automation

As identified by the ANVOA testing for the "Views on Autonomy" section, only item 4—AHI had any statistical significance among the ranking groups of participants. However, due to the question asked in item 4—AHI, the reason for this difference may be due to the variation in rank, as participants of a higher rank will have experienced an increase in levels of autonomy throughout the duration of their careers when compared to participants that have only recently begun their maritime career.

For the "Trust in Autonomy" section, only Item 3—"*Alarm*" had any variance among the participants' rank. This may be due to the variation in watchkeeping experience levels within the ranks, with lower ranks having a stronger belief that alarms increase SA compared to participants of a higher rank. Again, this can be expected as more experienced officers will understand the different alarms that sound on the bridge, some of which may be false alarms or routine alarm testing.

For all three SJQs, the groups tended to answer in a similar manner. For SJQ1, the UQ group varied their choices among all the responses, with only R3—"*Disregard the paperwork, remove navigational control from autopilot to manual and continue with the rest of the watch at the helm of the vessel*" being firmly highlighted as the "Least Appropriate" response. This indicates that the UQ group may value their paperwork and view it as a priority of navigational officers. Conversely, for the OOW and Mst groups, choices showed variation among the responses with R2—"*Call the captain of the vessel to inform them of the situation and ask for a lookout to concentrate on the position of the vessel whilst you complete your paperwork*". This shows that participants of a higher rank will prioritise the safety of the vessel over paperwork.

For both SJQ2 and SJQ3, all ranking groups answered similarly, with the only exception being in SJQ3, where the UQ group believed that R2—"*Conduct an emergency engine slowdown and adjust the autopilot to starboard, with the aim of bringing the vessel away from the shoreline*" slowing down the main engine would be more appropriate than R3—"*Slow the main engine down and bring the engine to full astern to reduce the forward momentum of the vessel. Additionally, use the vessel's thrusters to aid course correction*", whereas the OOW and Mst believed the opposite. This may be due to the inexperience of vessel navigation and unfamiliarity with the situation among the UQ group. However, both questions have shown that despite there being differences in the responses, the overall view remains approximately the same to the total figures when treating the participants as a homogenous group.

With the correlation between participant age and rank being identified, it is possible to assume, in conjunction with prior research, that officers of a higher rank would have more trust in decision aids than lower-ranked seafarers [43]. However, the findings of this study contradict this statement, as participants tended to answer in a similar manner to each other despite their rank.

5.3. Limitations

In conducting a survey study, the main limitation will be the number of participants. By increasing the number of participants, it would then be possible to formulate definitive statements for navigational officers' opinions towards autonomy. The results of this study could be used in designing further investigations of the fault recognition of navigational officers through the use of bridge simulators, for example. Using the SJQ as a method to question participants was successful. However, structuring them as a ranking question proved to be difficult to analyse due to the sample size of participants. Adopting a method that combines SJQ with a single best answer approach (SBA) for future research would be beneficial in terms of data analysis.

6. Conclusions

With the maritime industry aiming for the introduction of autonomous systems in the near future, it is imperative that navigational officers fully understand their role. By reaching out to current officers about the intricacies and difficulties of current systems, it will be possible to develop a system that will ensure the success of autonomous shipping.

This study analysed the attitudes of seafarers regarding autonomous shipping. Developing the survey in three definitive sections allowed the opinion of autonomous shipping to be voiced from the seafarer's perspective, while addressing the differences between how seafarers can recognise a suitable course of action in the event of a fault in comparison to their conduct when experiencing the same fault in a real-life setting. Overall, the conclusion is that the seafaring cohort assessed are positively receptive towards the introduction of autonomy. Most participants understood that while autonomous shipping will bring undoubted challenges such as potential job insecurity and bias towards the system, they were confident in trusting the system, providing they were suitably trained in using it. Moreover, the situational judgement section of the survey provided a greater insight, as scenarios that have been used in other studies and real-life maritime accidents were recreated to understand whether seafarers could identify a suitable course of action to take in the event of a developing incident. The results of the SJQs showed that seafarers could successfully identify suitable responses to the various scenarios that greatly differed from the approach taken by the individuals in the real-life version of events.

By conducting this study, it has been found from the "Views on Autonomy" section that officers agree that automation aids them in their daily role as the OOW. Understandably, there are concerns due to the unknown nature of how autonomy will be implemented, regarding the longevity of careers and the matter of trust in the unknown systems. However, if handled with care, the results of this study indicate that the crewing side of the maritime world will welcome the change. Naturally, there are concerns among the participants regarding the "Trust in Autonomy" section. However, the participants acknowledge this fact and are aware from first-hand experience that systems are not infallible, yet with sufficient training and supervision, the cohort are willing to place trust in the system.

While the assumption of this study could be that higher-ranking officers would have less trust in an autonomous system, it was found that overall, the participants' rank did not factor much into the results. The rank of a participant was a small factor in the SJQ, however, with both fully qualified officer groups tending to answer the questions with the same thought process. This can be attributed to the UQ group having less knowledge and experience of the procedure in such situations. The participants displayed a strong understanding of each question and most identified the response that would be the "Least Appropriate" in each instance. However, this contradicts what has occurred in previous studies [45] and real-world incidents [5], meaning that while the seafarer has the ability to identify a correct answer, there is a disconnect when applying their knowledge in practice.

The novelty of conducting a study in this manner is that it allows for a wide variation of participants to voice their opinions. Moreover, developing scenarios similar to the situational judgement allows participants to display their knowledge and understanding using a tool that can be distributed to a large population. This will prove essential in the development of MASS, as the seafaring cohort have previously expressed their concerns with autonomous shipping in past research. Subsequently this concern can be consolidated with the findings in this study; this could ultimately impact the introduction of MASS in a positive manner for both the workforce and the maritime industry.

With 2050 being the year that IMO have identified as the upcoming milestone for the maritime industry, it is imperative that seafarers understand the challenges that lie ahead for them. Autonomous technology has the capability to revolutionise the world of shipping, and if the correct precautions are taken among the seafaring population, then the possibilities are endless for the maritime sector. This study has shown that while the attitude towards autonomy remains positive overall, there are some concerns regarding the ethical decisions and responsibilities of those developing the unmanned vessels. Furthermore, between the varying ranking groups of officers, the viewpoints tended to remain constant; generally, officers are embracing the technological strides that the maritime industry is making. Adapting this study as a baseline to acquire further knowledge on the views that seafarers have will benefit ship owners, shipping companies, and system designers as the industry makes one further step towards the unknown.

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