Situation Awareness improvements by Augmented Reality implementation to marine navigation

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Abstract

Human error is an important factor in maritime accidents nowadays. They are directly or indirectly related to them. In cases such as collision and groundings, the greatest immediate causes for maritime accidents have been found to be a lack of situation awareness.

On the other hand, with the growing interest in Augmented Reality worldwide and the enhancements it permits, it became interesting to investigate if there could be a possibility to solve issues of situation awareness and human error with Augmented Reality projections to marine navigation.

Therefore, the main purposes of the thesis are to investigate if Augmented Reality can be helpful in building up and maintaining Situation Awareness for marine navigation, and to support any future studies made on the topics of Situation Awareness and Augmented Reality as related to marine navigation.

The research question is: “Can Augmented Reality be helpful in building up Situation Awareness in marine navigation?”

The research methodologies used were literature-based research and quantitative research by means of a questionnaire.

The results although positive and inclining towards the benefits of Augmented Reality to improve Situation Awareness in marine navigation, cannot be regarded as conclusive and further empirical research on simulators or at sea are needed.

In conclusion, the investigation of the actual benefits to Situation Awareness by Augmented Reality must be transferred and sought through the specific operating system used.

Language: English

Key words: Situation Awareness, Augmented Reality, marine navigation

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Glossary & special terms

AR: Augmented Reality.

ARPA: Automatic Radar Plotting Aid.

Collision Avoidance: The officer assigned Collision Avoidance provides collision avoidance data and recommendations to the Conning Officer.

ECDIS: Electronic Chart Display and Information System.

HMD: Head-mounted Display.

INS: Integrated Navigation System.

MPA: Marine Protected Area.

OOW: Officer of the Watch.

Open waters: At sea when not enclosed by land, ice, or other barriers.

RADAR: RAdio Detection And Ranging.

Situation Awareness (SA): Knowing what is going on around you (Endsley, 2000).

Level 1 SA (Perception): Perception of cues (Endsley, 2000).

Level 2 SA (Comprehension): Apart of perceiving and attending to information, it includes the integration of multiple pieces of information and a determination of their relevance to the person’s goals (Endsley, 2000).

Level 3 SA (Projection): This is the highest level of SA, the ability to forecast future situations and events (Endsley, 2000).

1 Introduction

With every accident or near miss that risks loss of life, injury and suffering, we ask ourselves if something could have been done differently in the measures and procedures to impact the outcome of an accident and prevent it from happening.

When there is room for improvement we use any tools that are available to us to reduce the number of such type of accidents, or at least the severity of them. An example to this is the case of Ms Estonia that sank in 1994 in the Baltic Sea which triggered new regulations imposed for Ro-Ro vessels and passenger vessels with new design, management procedures and stability condition requirements among others.

In order to prevent an accident, apart from having a new design or management procedures, the introduction of new devices and systems granted by the advancement in technologies has also provided less incidents in the maritime field. But not all technology implementation has been beneficial. Technological advances have also brought new elements that were non-present before such as complacency, poor system knowledge and inadequate system design. These have been found to be among the most important human-technology errors related to accidents nowadays.

On the other hand, based on the number of navigational claims, the Swedish Club has analysed that in most accidents, human error is the most important factor. Collision and grounding constitute the biggest claims after machinery and equipment faults (The Swedish Club, 2014). From the same study, it appears that in collision and grounding cases, a lack of situational awareness, among others, is the greatest immediate cause.

Conversely, the field of Augmented Reality technology, has shown a growing interest worldwide. Companies dedicated to this type technology have been looking to its incorporation to many areas of the daily life. This type of technology, AR, enables its user to mainly see projections of the digital world combined onto the real-world. It therefore allows for further information to be perceived by the wearer. Would there be a possibility to solve issues of situation awareness and human error with Augmented Reality projections in marine navigation?

As of the incorporation on ships nowadays, the question remains on the real practicality and availability of such systems for immediate implementation.

1.1 Objective & Research question

The main purpose of this thesis is to investigate if Augmented Reality can be helpful in building up and maintaining Situation Awareness for marine navigation.

The secondary purpose of thesis work/project is to support any future studies made on the topics of Situation Awareness, Augmented Reality as related to marine navigation.

The research question reads:

"Can Augmented Reality (AR) be helpful in building up Situation Awareness (SA) in marine navigation?"

1.2 Contexture

As it is seen, the order of chapters in which this thesis is organized allows the reader to understand the idea behind the research question.

Following the table of contents, the glossary & special terms section seeks to explain terms that are used in the text about Situation Awareness and Augmented Reality as well as maritime navigation terms.

After the introduction, a short background and main problem due to the lack of situation awareness in ship manoeuvres is presented in the introduction section. It is followed by the objective & research question. Augmented Reality technology is discussed in chapter 3, focusing in the range of possibilities that this new technology offers and its possible use on ship bridges.

Chapter 4 deals with Situation Awareness, the mechanisms and processes involved in SA and aspects that influence decision making, errors and SA measurement. As SA represents a core part of the study, special effort has been put to explain its structure.

In chapter 5, are discussed the Research Methods used and the Collection of data.

It is followed by chapter 6: Situation Awareness, Augmented Reality and ship navigation that deals with the network between SA and AR in ship navigation.

Conclusions, research question answer, limitations and further research are dealt with in Chapter 7.

Chapter 8 displays the references used in this thesis and chapter 9 is comprised by the Appendices.

“Experiment visualization & scenario layouts” used to as prelude to answer the thesis questionnaire in Appendix II is presented in Appendix I. Graphs from the answers of the audience to the thesis questionnaire are displayed in Appendix III.

2 Augmented Reality technology

2.1 Introduction

Augmented Reality (AR) can be described as an improved view of our world. This is done by implementing to the real world, through Head-Mounted Displays (HMD), virtual objects. Unlike with Virtual Reality (VR), where a complete view is virtually created and none of the real environment is displayed, AR uses see through glasses in order to achieve the desired blend between the real and virtual environment. Therefore, a more appropriate definition for augmented reality is the interaction of superimposed graphics, audio and other sense enhancements over a real-world environment that is displayed in real-time.

Although the intent of realizing this idea dates back to the 1930s, the concept of Augmented Reality as such has been known for as far back as the 1960s. (Krevelen and Poelman, 2010)

Recently in the 1990s, Tom Caudell, a Boeing researcher, first coined the term to describe a digital display used by aircraft electricians that incorporated virtual graphics onto physical reality.

It is now due to the advancement in technology in the recent decades, that this type of technology has become more available and practical to operate.

Although various virtual reality and augmented reality technologies are in development phases or have been released as prototypes, there are studies suggesting that within the industry, AR is to suffer an economic boom in the next decade. (business.com, 2017)

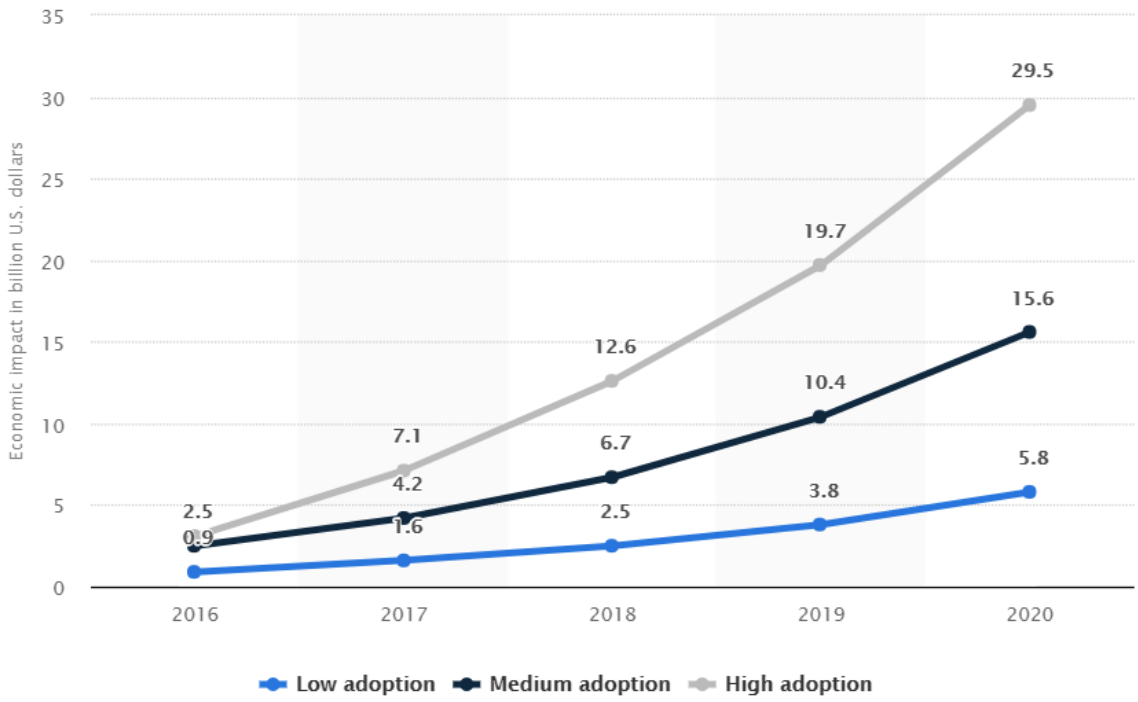

Figure 1: Graph depicting economic impacts of virtual and augmented reality technologies worldwide from 2016 to 2020 (in billion U.S. dollars) (*Global virtual & augmented reality economic impact 2016-2020 | Statistic*, 2016)

Due to their functionalities, Augmented Reality and Virtual Reality have different practical uses. In most cases, Virtual Reality is used for videogames and trainings in fields such as, medical training, mental health, military, education and construction.

2.2 Augmented Reality technology in other branches

Augmented Reality, due to its functionality can be used through handheld devices such as smartphones, or augmented projections to headsets.

Some companies such as Google & Microsoft have second-generation headsets in development that are expected to be released in 2018. These will bring a wider variety of features and uses:

> "Mixed reality has the potential to help customers and businesses across the globe do things that, until now, have never been possible. Mixed reality experiences will help businesses and their employee's complete crucial tasks faster, safer, more efficiently,

> and create new ways to connect to customers and partners."(*Microsoft expands HoloLens headsets to 29 new markets, now up to 39 | TechCrunch*, 2017)

As Augmented Reality has been incorporated into smartphones, software developing companies are looking to use this technology to make it possible for customers have a real-time preview of their products by displaying the virtual objects into the customer's phone while using the device's camera to help decide if an item is suitable or not. Among the companies with this type of Augmented Reality use in mind is IKEA:

> "IKEA Place makes it easier to make buying decisions in your own place, to get inspired and try many different products, styles and colours in real-life settings with a swipe of your finger"(*IKEA To Transform Shopping Experience With Augmented Reality*).

Another branch in which Augmented Reality is expected to leave a mark is school education. Among its uses are representations of mathematical graphs or a human brain that otherwise would be represented in 2D on a whiteboard or paper and would therefore be more challenging to explain and understand.

This new way of display could as well engage students in a more interactive type of learning as students are more motivated and engaged and could possibly understand subjects better and learn faster.

Similarly, the implementation of Augmented Reality has also been looked upon in the aviation industry. The simplification and clear display of own-ship readings such as altimeter, fuel pressure, oil temperature, heading, traffic information display, no-fly zones, or for example the path to follow towards a runway in landing situations, might be of aid for pilots. (Avionics, 2017)

Figure 2: Image representing AR projections on aviation prototype. (*Aero Glass*)

This type of information display, suggests an increase in situation awareness and therefore better decision making for pilots. As air traffic congestion continues to increase, and systems become increasingly loaded with information, it is apparent that these types of systems could optimize part of the work done by pilots and be part of daily routine in the near future.

Similarly, in marine navigation, the Officer of the Watch's situation awareness can become reduced when the amount of information that needs to be processed becomes too great. This information overload takes its toll on the working memory of the Officer of the Watch thus reducing the chances to reach the ideal Situation Awareness. These topics of Situation Awareness are discussed and explained in the next chapter, Chapter 3: Situation Awareness (SA).

2.3 Head-mounted device (HMD) use

2.3.1 Introduction

To start, there is a distinction to be made clear between the terms Head-up display (HUD) and Head-mounted display (HMD). HUDs are any transparent units that display projections to a screen. The screen from which the projections are seen, is fixed to the structure of the body itself, for example of a fighter airplane. The same concept of projection display is used in HMDs but instead of having the screen fixed on the structure of the apparatus, it is mounted directly on a glass or helmet.

Worth mentioning, is that the projections and real world seen outside the window would need to be synchronized and aligned. This meaning that the device should be able to follow and track the operator's movements (operator head movements but also if the operator would move otherwise. According to the "6 degrees of freedom") in order to display the data correctly.

This type of monitoring by the device would be made possible by the device's sensors. The sensors, as already seen in several HMDs in other industries, include digital cameras, accelerometers, GPS, gyroscopes and compasses. Moreover, some devices are able to offer Wi-Fi antennas and Bluetooth capabilities, such as the Google Glass.

2.3.2 Bridge use

The Head-mounted device that would be used by the OOW is no different in functionalities and purpose from other HMDs intended for AR used for videogames, course trainings, etc.

Figure 3: HMD use tested in Terschelling's Willem Barentsz Maritime School, The Netherlands (ACCSEAS)

In the above figure, the HMD, similar to conventional eyeglasses, consists of lenses. Into these lenses is projected the video feed of augmented objects with a set transparency that does not impede the ability of the user to see through it. Thus, overlaying the real and projected sight.

The HMD projection of objects, in a sense following the Integrated Navigation System (INS) principle would be fed by the inputs of the different bridge navigation resources such as Automatic Identification System (AIS), Radio Detection and Ranging (RADAR), Automatic Radar Plotting Aid (ARPA), Electronic Chart Display and Information System (ECDIS), Gyro Compass and Magnetic Compass, among others. Important to remark, is that it would be dependent on the above-mentioned sources or inputs, meaning that if the inputs are erroneous, the display would not be applicable to the outside view.

Another implementation of which this new way would be beneficial is the usage of user charts. Where the OOW could input caution areas, shallow area boundaries or also no-go areas, Marine Protected Areas (MPAs), environmentally sensitive areas with regards to ballast, sewage, greywater and other discharges. As well as ship/company specific procedures.

Perhaps the most evident benefit is the projection of the known "Simulated track prediction". This prediction tool unlike its predecessor the "Path prediction" (which integrated simplified motion models), would give the navigator a direct view of the ship's movement and path with the current rudder and speed orders.

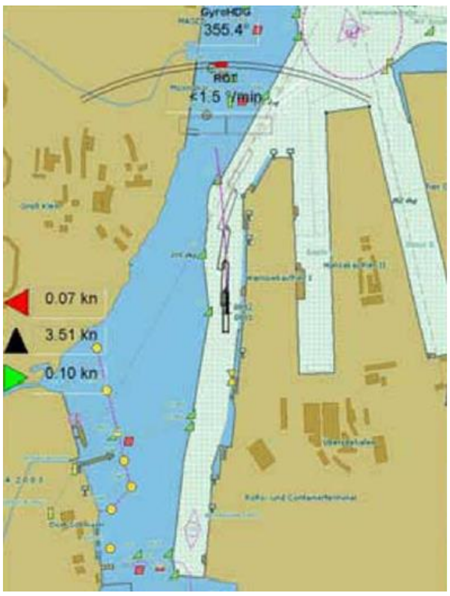

Figure 4: Maneuvering prediction displayed on ECDIS (Benedict, et al., 2010)

As it might seem noticeable, AR projection onto HMDs is appealing as most information is readily available and collected into one system thus allowing the bridge team to spend more time looking out the window than down into the bridge's scattered resources. This procedure is particularly seen in the figures below (Procee *et al.*, 2017):

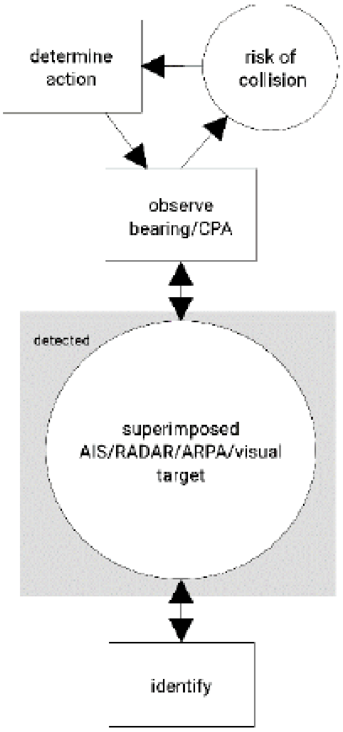

Figure 5: Information flow map for ship-to ship Collision Avoidance introducing AR.

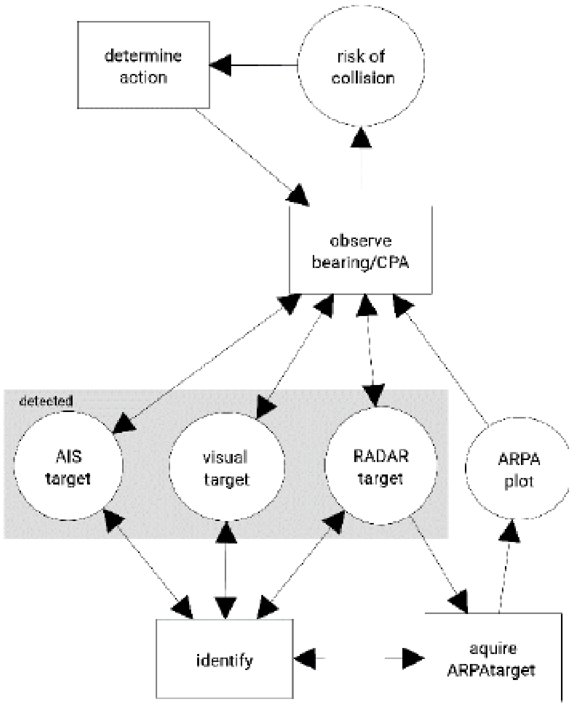

Figure 6: Information flow map for ship-ship collision avoidance by conventional approach.

With regards to the projected objects, they would be so called "locked" to their relative position to the ship on the chart as shown on the figures below.

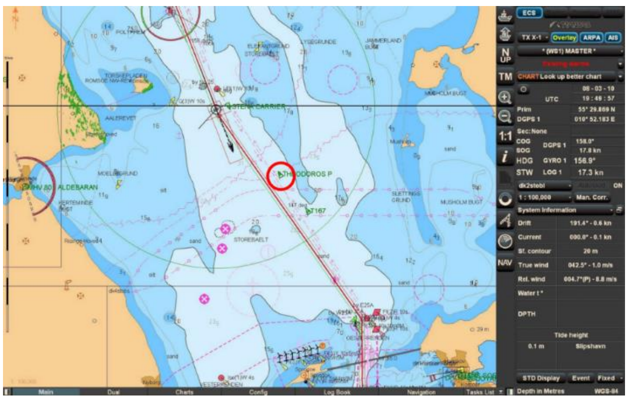

Figure 7: Target displayed on ECDIS (Expo)

Figure 8: Same ship visualized through AR projections (ACCSEAS)

Figure 9: Example of final outside view through AR projections (de Vlaming, et al., 2013).

3 Situation Awareness (SA)

3.1.1 Introduction

The study of Situation Awareness started only in the 1980s (Endsley, 1995). Interest in the topic started in the field of aviation as it was noticed that SA was linked to performance and decision making.

The area of focus of the studies was to understand the way in which operators acquired and maintained SA in order to create a system that enhanced a better SA. Simultaneously, this objective motivated the need to seek a deeper understanding in the cognitive processes involved.

3.1.2 Definition

Situation Awareness (SA), is commonly described as "knowing what is going on around you at a given moment" (Endsley, 2000). Related to the task of the operator, SA is defined in terms of the actual goals and decision tasks of the navigator.

In other words, Situation Awareness is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future". (Endsley, 2000)

The most agreed concept for the foundations of SA is divided into 3 levels:

- Level 1 SA: Perception: SA is derived from all sources of information through tactile, visual, aural, olfactory or taste receptors.
- Level 2 SA: Comprehension: As the senses acquire data from the environment, it is combined, interpreted, stored and retained as information. This level 2 takes care of integrating multiple pieces of information and determining which is of relevance to the operator's goals.
- Level 3 SA: Projection: Is the ability to project current events and dynamics to anticipate future events and their implications.

Important to note is the significance of time in SA. As referred to understanding the available time until some event occurs, or an action must be taken. Precisely in the scope of a changing environment where a person's SA must constantly change or become outdated and inaccurate.

Deriving from a great array of factors and influencers, the operator can decide what to do about the situation and carry out the necessary actions. SA therefore is represented as the main precursor to decision making; however, many other factors came into play in turning good SA into successful performance. An example to this, can be seen below:

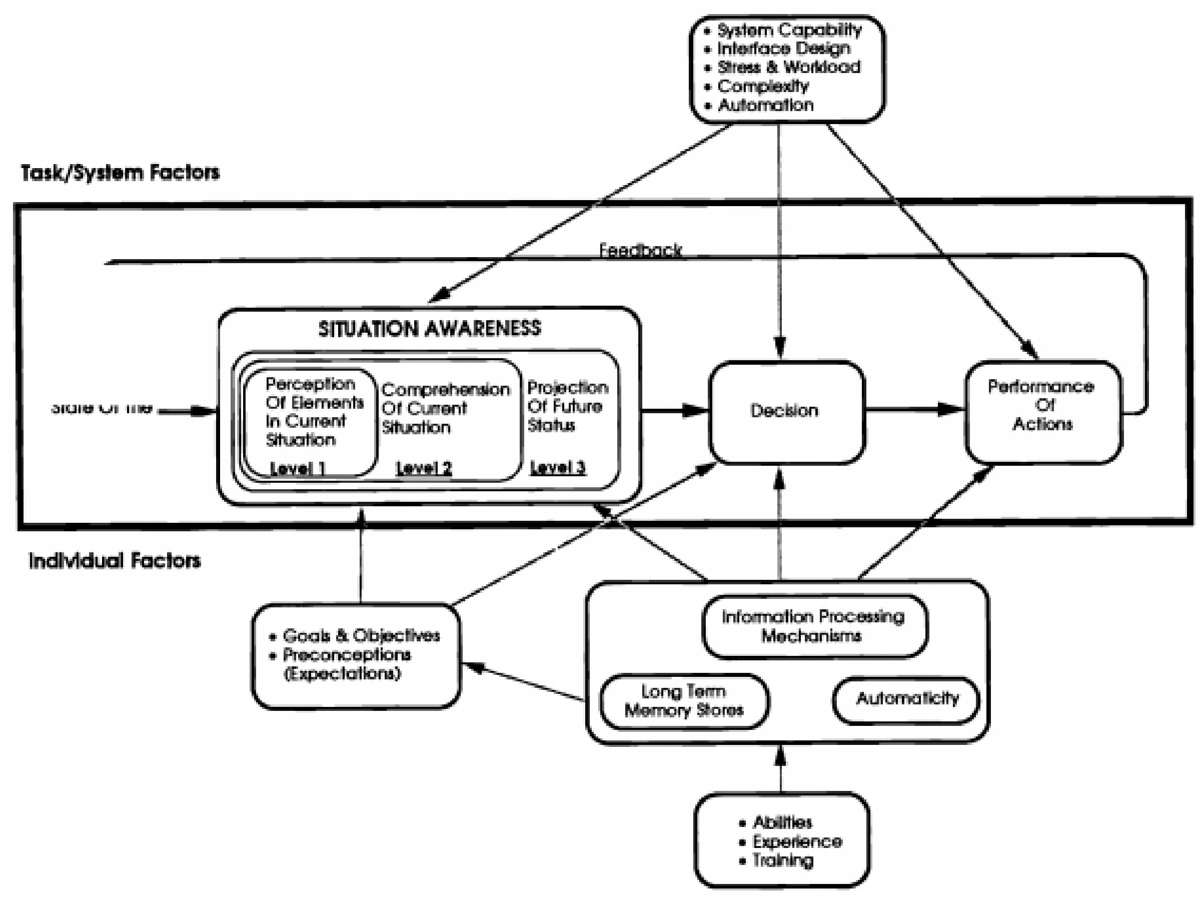

Figure 10: Model of Situation Awareness in dynamic decision making. (Endsley, 2000)

3.1.3 Mechanisms and processes involved in SA

For the purpose of this Thesis, the parts that were most relevant are those related to the acquisition of information (SA Level 1: Perception), working memory impact on the operator (SA Level 2: Comprehension) and the ability to project possible outcomes by the operator (SA Level 3: Projection) that are stated above.

The way in which people pick and choose which information is relevant, how they weave it together and interpret it in a changing environment that follows the operator's goals, is a complex process that is only glanced over below.

3.1.3.1 Working memory (WM)

> "Working memory is a cognitive system with a limited capacity that is responsible for temporarily holding information available for processing" (Control, 1999)

Working memory (WM) is regarded as one of the most important parts of human cognition. Although research in this area has been conducted for decades, only limited information is known to be certain.

Among what is known is that WM results from the interaction between several component processes which include attention, prospection, and perceptual and long-term memory representations. It is also known that it is related on the objectives and structure of a task at hand and the context in which the task is performed.

One of the most important characteristics of WM, is that it is highly limited in how much information can be held "in" at a given time. With individual differences, most estimates an average capacity limit of 3-4 simple items (Vogel, Woodman and Luck, 2001) can be remembered with accuracy. Once it exceeds this number, performance to remember with such good accuracy decreases.

Although some individuals have been able to recall up to over 80 items with "chunk" memorizing training, the lower end individuals, as research seems to suggest, suffer more difficulties ignoring distracting information than do high-capacity individuals (Fukuda and Vogel, 2011).

This is in part because they are slower at disengaging attention to irrelevant information that captures their attention. Thus:

> "…, the ability to efficiently deploy attentional control in overloading situations appears to be the common thread that connects working-memory capacity to an individual's ability to perform many complex cognitive tasks" (Eriksson et al., 2015)

When a situation becomes bloated with information that is relevant to the operator, it takes constraint on the abilities to create the ideal SA. An example related to this issue was found to be emphasized in novice operators who cannot retrieve from experience and long-term memory (thus reducing their mental workload) as experienced operators could. Experienced operators had more mental mechanisms to aid them to overcome mental workload. (Endsley, 2000).

Although this is true, even experienced operators may be faced with so much information that attention and working memory constraints that it can be an issue.

An example of the many tasks and constraints directed to the OOW can be seen below (Procee et al., 2017):

- Efficient sailing:
    1. With considerations to slow steaming when possible (maximum use of tidal streams, load optimisation in shallow water, etc.)
    2. Avoidance of environmental boundaries (discharge locations for "grey" and "black" water, use of incinerators, bilge concentration control, etc.)
    3. Great circle vs rhumb-line (Climate and weather routeing)
- Comply with Estimated Time of Arrival (ETA):
    1. Speed in relation to ETA
    2. Acceptable time margins in relation to ETA
    3. Allowing for rest of logistic chain (pilots, tugs, Estimated time of berthing and departure)
    4. In relation with intermediate passages (narrows, bridges, locks)
- Avoid damage to own ship and cargo
    1. Ship dynamics (Sea state (swell, waves) pitching and temperature)
    2. Cargo stowage constraints
    3. Insurance constraints
- Pre-planning cargo operation

- Be a team player (multiple person bridge operations)
    1. Culturally aware
    2. Hierarchy aware
    3. Use proper procedure
    4. Adhere to procedure
- Check integrity of ship systems
    1. Sensors (GPS, Gyro, LOG, RADAR, ARPA): ECDIS overlay (position + gyro check), visual overlay (AIS & ARPA targets)
    2. Target's AIS collocated with RADAR-ARPA
    3. Communication equipment
    4. Visibility
    5. ECDIS: Safety settings, keep updated with Notices to Mariners and Preliminary & Temporary promulgations, mode of operation
- Avoid collision
    1. Overhead objects (power cables, bridges)
    2. Ships (status, Closest point of approach and Time to closest point of approach distance bearings, rules)
    3. Floating and fixed objects (Ice, wreckage, NavAids, offshore constructions)
- Avoid grounding
    1. Under Keel Clearance control (speed and squat, ship dynamics (rolling, pitching)
    2. Checked planned track (Charted dangers, published new dangers, tidal height)
    3. No-go area, safety contour-line (Taking into consideration the ship maneuvering characteristics)
    4. Contingency plans (available navigable space)
    5. Minimum Under Keel Clearance based on survey quality
- Safeguard own ship
    1. React to alarms
    2. Generate alarm
- Communicate and report
    1. Other ships (SAR operations, maneuvering, react to emergency call on VHF)
    2. Intern ship (Social, collegial advice, logging events, training apprentices)
    3. Authorities (VTS, mandatories)

4. Manufacturers (In case of failure or anomaly)
5. Company (Maintenance reporting, personal administration)

- Do it continuous (one man bridge operations)
    1. Without errors
    2. In real time
    3. Abiding watch schedule
    4. Irrespective of one's own physical health or condition or state of mind
    5. Trustworthy, dependable
    6. On any ship
    7. At any time of the day
    8. In any situation

3.1.3.2 Attention

Attention as defined in psychology:

> "It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought." (James, 1890)

Similar to working memory, attention is limited. The way in which we focus our attention is influenced by the "perceptual salience" of environmental cues (the degree to which these cues draw our attention) and the individual's meaningful direction of attention towards something.

Many factors will dictate how people direct their attention and therefore affect Situation Awareness. These include learned scan patterns by the operator, expectations from the environment and other information that has already been processed and could be related to the present task. Therefore, the information that is attended to depend on the importance that the operator believes it has.

Interestingly, as seen above in working memory, distractions play an important role. A study in the field of aviation found that the most frequent factor associated with Situation Awareness (SA) incidents (35.1%) involved situations where all information was present but was not attended to by the operator due to momentary task distractions or high workload levels (Jones and Endsley, 1996).

3.1.3.3 Long-term Memory (LTM)

Long-term memory is commonly defined as the stage at which information is held indefinitely as contrary to working memory. Through various processes, information is encoded from short-term to long-term memory and becomes resistant to change. Although used to bring information from memory, it is subject to fading through the natural process of forgetting. Rehearsals/recalls may be helpful with the ability to keep information in long-term memory and limiting it from fading away.

On the topic of LTM and its relation to Situation Awareness, information stored here is used in pattern recognition processes and coding. The parts of the environment that are perceivable remain in working memory as a highlighted subset of LTM through either localized attention or automatic activation. (Endsley, 2000)

Bringing the different parts together, Situation Awareness is the product of acquired external information, working memory processes, and the long-term memory stores activated and brought to bear on the formation of the internal representation.

3.1.3.4 Cognitive processes involved in Situation Awareness

- Mental models and schemata are believed to be central mechanisms for overcoming limited working memory constraints to form Situation Awareness under challenging conditions.
- Associated to mental models are pattern matching processes which help in SA. These having found to be linked to decision making. (Endsley, 2000)
- Goals also seem to be critical for the forming of Situation Awareness. They help direct attention in scanning an environment and declaring what information is important. Important to highlight is that there are two types of processing approaches: data-driven (where environmental cues may indicate new goals that need to be active) and goal-driven processing (where attention is directed across the environment in accordance with active goals). Switching between these two is important for successful performance in many environments. (Endsley, 2000)

- Expectations from mental models, prior experiences, instructions, or communications can have an impact as well as on how we direct the attention through the environment and the way in which information is taken in.
- Another cognitive process that might affect the creation of Situation Awareness is automaticity. Automaticity, deriving from experience, is a process that comes through high levels of routine for example in tasks of pattern-recognition and action-selection. In use, it gives good level and high speed of performance but may adversely affect SA by making operators more prone to not noticing information that is "out of the ordinary". Meaning that attention may not be given to information that is outside the routine sequence.

3.1.4 Decision Making

As later discussed, decision making is influenced by our perception of the environment (cues/knowledge), expectations and goals.

A way to discuss how decision making is connected to Situation Awareness is by the use of retrospective accounts of critical incident reports. Through these retrospective accounts, it is seen that the shifts in Situation Awareness are directly linked to the adoption of the course of action in a situation. The process that is used for decision making is thought to follow a path similar to:

Cues and knowledge are derived from the environment, expectations of potential outcomes are displayed by the operator, goals are unveiled, and decision points are derived. An example to this process can be seen below, in a Situation Awareness record from a tanker incident:

SA-1	
Cues/knowledge	overturned truck on highway; ruptured fuel tank; engulfed in flames; intense heat (highway signs melted); another truck 50 feet away; citizen rescuing driver
Expectations	potential explosion; life hazard
Goals	complete the rescue; extinguish fire; block traffic
Decision point-1	aid in driver rescue
Decision point-2	call for additional units, rescue unit, police, foam
SA-2 (elaboration)	
Cues/knowledge	additional equipment arrives; fire more involved
Expectations	chance of explosion is less
Goals	protect firefighters; gain needed resources (water)
Decision point-3	set up covering streams
Decision point-4	hook up pumper hoses
SA-3 (elaboration)	
Cues/knowledge	protective streams functioning; foam trucks arrive
Expectations	fire banking down
Goals	optimal truck placement; set up foam operations
Decision point-5	directed truck and foam placement (using angles, impact, and wind direction cues)
SA-4 (shift)	
Cues/knowledge	storm drain behind operations blows up; determines jet fuel has leaked into storm sewers
Expectations	fire will span out of control
Goals	check fire and prevent spread
Decision point-6	call second alarm

Figure 11: SA record from Tanker incident. (Endsley and Garland, 2008)(Klein, 2000)

3.1.5 Errors related to SA. Performance and expertise

Some ways have been found to be useful to help in Situation Awareness in individual and team levels. This training in both levels is important that they are implemented as complement to the other to see the best benefits.

Loss of Level 1 SA—Failure to correctly perceive the situation (76.3%)
- *Information not available (11.6%)*
  - system & design failures
  - failure of communication
  - failure of crew to perform needed tasks
- *Information difficult to detect (11.6%)*
  - poor runway markings
  - poor lighting
  - noise in the cockpit
- *Information not observed (37.2%)*
  - omission from scan
  - attentional narrowing
  - task related distractions
  - other distractions
  - workload
- *Misperception of information (8.7%)*
  - prior expectations
- *Memory error (11.1%)*
  - disruptions in routine
  - high workload
  - distractions

Loss of Level 2 SA—Failure to correctly comprehend the situation (20.3%)
- *Lack of/incomplete mental model (3.5%)*
  - automated systems
  - unfamiliar airspace
- *Incorrect mental model (6.4%)*
  - mismatching information to expectations of model or model of usual system
- *Over-reliance on defaults values in the mental model (4.7%)*
  - general expectations of system behavior

Loss of Level 3 SA—Failure to correctly project situation (3.4%)
- *Lack of/incomplete mental model (0.4%)*
- *Over-projection of current trends (1.1%)*
- *Other (1.9%)*

Figure 12: Sources of Situation Awareness error in aviation. (Jones and Endsley, 1996; Endsley and Garland, 2008)

The following tasks are from the aviation field but can be transferred to the maritime field due to the similarities. They discuss facts from studies related to proper SA of pilots:

- Task management: interruptions, task-related distractions, non-task related distractions and workload are directly involved with the forming of proper SA. Research found that those better performing crews used their abilities to accurately assess the importance and severity of events and tasks, as contrary to those who dealt with an event interruption and those who used a procedure-based strategy.
- Development of Comprehension (Level 2 SA): Pilots were also found to perform poorly if they are unable to properly gauge the temporal aspects of the situation, risk levels involved and both personal and system capabilities with dealing with situations.
- Projection and Planning (Level 3 SA): Research in the aviation field also showed that experienced pilots free time was used more often trying to anticipate future

happenings. This gave them time and knowledge to better decide on their course of action to meet their objectives.

- Information-seeking and self-checking activities: Pilots with higher levels of SA were actively seeking out critical information making them quicker to notice trends and react to events.

There are as well ways to improve SA through training. These trainings include exercises that involve tasks related to those seen above such as attention-sharing, task management, contingency planning, information seeking and filtering among others.

Interestingly, a great measure to help in the acquisition of SA is put on the use of "pre-flight" briefings. These briefings, which in the maritime context translate to "pre-arrival" and "pre-departure" briefings, allowed for expectations for the trip ahead to set thus, as seen previously helping with the acquisition and interpretation of information that is perceived from the environment. Additionally, constructive feedbacks also were seen to be beneficial.

Lastly, the weight of expertise in the creation of SA is huge. There is research that points that more experienced pilots tend to have better perception of their own abilities, therefore being able to know what the limits are as opposed to novice pilots who tended not to know the limits of their knowledge and abilities therefore prone to be more risk-taking (Endsley and Robertson). As previously discussed, with expertise comes the internal development of internal models by the operator which help in directing the limited attention in a more effective way, provide means of integrating information without loading working memory, and provide a mechanism for creating projection of future system states (Endsley, 2000).

3.1.6 SA Measurement

Situation Awareness measurement allows us to better assess and understand the amount of SA that is ideal for an operator, but it also allows us to apply it for the evaluation of a system design. In this system design, processes in attention, memory and workload are evaluated as part of the operator's SA. With the purpose of creating a system design that enhances the abilities of the operator to a better outcome.

4 Research Methodology

4.1.1 Method

For the purpose of the research, guided by Mr. Procee's advice, it seemed logical to start at the core of the study, the Situation Awareness. A literature-based research on Situation Awareness mainly from "Situation Awareness Analysis and Measurement" book enabled a better understanding of the elements, processes and areas that are of most importance to being aware in an environment.

Having grasped the depth of the processes of Situation Awareness, the next thing to advance with was my own visualization of a model that would display augmented projections on marine navigation.

The multiple examples stated in the book "Situation Awareness Analysis and Measurement" with regards to aviation helped to picture how would certain aspects and processes of Situation Awareness be affected by the use of Augmented Reality.

Important as well was Mr. Procee's "MNARS Experiment Design" set-up listed in the references list. It gave an idea of different kinds of scenarios that could benefit Situation Awareness by Augmented Reality.

Next, in order to be able to create a quantitative research by the means of a questionnaire, the audience to whom it would be intended to needed to be introduced to the topics by unpacking Situation Awareness and Augmented Reality in navigation (Appendix I). Adding to this, was the setting up of several scenario visualizations that were imperative to understand before answering the web-based questionnaire.

The questionnaire itself focused on asking from the respondent's maritime background on Situation Awareness's core areas of perception, comprehension and projection as applied to ship navigation using Augmented Reality projections.

4.1.2 Collection of Data

Performing a literature-based analysis, I noticed that there had been previous studies, articles and publications on the use of Augmented Reality through HMD's in other industries such as aviation and medicine, mainly focused on training purposes.

A few studies on the use of HUDs (Holder and Pecota) and HMDs (Vlaming and Verhoef, 2013) (Lukas, Vahl and Mesing, 2014) (Safahani *et al.*, 2005) in marine navigation was also available which gave insight of practicalities.

Guidance on the topic of Situation Awareness and Augmented Reality in marine navigation was granted by Mr. Stephan Procee. Who advised to start by immersing myself into the topic of Situation Awareness dealt with in the book "Situation Awareness Analysis and Measurement" by Mica R. Endsley and Daniel J. Garland.

This process culminated in the creation of a web-based questionnaire (Appendix II) that was sent out to fellow mariners, college peers, and other maritime universities in Finland as well as spread through several maritime groups in Facebook.

In the thesis questionnaire (Appendix II), Questions 1a, 1b, 1c are straight forward in the sense that they ask from the reader about the core stages of SA. They are therefore required to visualize, provided the introduction to AR and SA in Appendix I, the way such new approach would work based on the maritime background experience. Questions 2 and 3 are supportive to Questions 1a and 1b related to perception and comprehension processes. Question 4 is related to the cognition processes such as working memory and attention in level 2 SA: Comprehension. The purpose in Questions 5 and 6 is for the surveyed to answer the likeliness and willingness to implement the AR approach to improve safety given training. These last two questions focus on asking if there are any benefits to the use of AR in navigation. Finally, it seemed relevant as well to ask about the navigation experience and age of the audience. Conveniently, the audience was from a varied age group with a majority in 5-10 and 10+ years of navigation experience.

Although a total of 44 questionnaire submissions were received, a reason for this could be the length of text that was presented to the surveyed in Appendix I prior to answering the questions. On the other hand, this also helped filter dishonest responses which in return increases the quality of the answers.

5 Situation Awareness, Augmented Reality and ship navigation

In support of the use of Augmented Reality to promote Situation Awareness in ship navigation, I have used the analyses on human aging and SA stated in "Situation Awareness and Aging" by Cheryl A. Bolstad and Thomas M. Hess. I have further supported them with the findings from the "Thesis Questionnaire" found in Appendix III.

Level 1 SA: Perception

Perception constitutes the starting point for the acquisition of Situation Awareness. This means that anything that cannot be observed through our senses cannot be consequently organized and analysed.

As our senses naturally deteriorate with age we fail to store information in a proper way affecting quality, quantity and type of information stored, therefore the foundation for good SA is not complete and the next stages of SA may seem unreliable.

The phenomenon of "slowing" that comes with age is an interesting one that helps support the use of AR. This process of older adults being slower translates to the decrease in speed by which they are able to target events in the environment and scan for relevant information.

In relation to this, another study found that the limitations associated with reduced processing can be smaller with the appropriate environmental supports to guide processing. Meaning that that gap in visual selection processes between younger and older adults is reduced or eliminated. Thus, unlocking the chance to focus on attention and eliminating the need of search.

Worth mentioning is that there are as well deficits in the registration in memory by encoding of contextual information associated with the event in the environment.

In all, this means that the effects of aging are less noticeable in environments where events are of a simpler nature and traffic is less congested. As of the use of Augmented Reality to improve level 1 SA, it is apparent that there are benefits already at this stage.

In answer to Question 1a of the Thesis Questionnaire statement: "I believe that Augmented Reality (AR) projections help the bridge team in Level 1 Situation Awareness: Perception." (I.e. to better notice buoys, lighthouses & other landmarks.), 98% or 43 of the surveyed 44 people answered “Agree” or “Strongly agree”.

Question 3, which is as well related to level 1 SA: Perception, was intended to further examine if there are benefits by AR. In answer to the statement: "I believe that Augmented Reality (AR) projections help the bridge team to better distinguish shallow/no-go areas.", a total of 89% or 39 people answered that they “Agree” or “Strongly agree”.

Level 2 SA: Comprehension

As of the characteristics of aging discussed by Bolstad and Hess on level 2 SA:

> “…aging may be associated with problems during Stage 2 SA acquisition, as reductions in processing resources and inhibition problems affect the ability of the individual to create an accurate mental model of the situation in working memory. Problems here include the ability to utilize effortful processing operations to deal with large amounts of and/or complex information, as well as difficulties in retrieving and utilizing information registered during Stage 1.”

Answering Question 1b with statement: "I believe that Augmented Reality (AR) projections help the bridge team in Level 2 Situation Awareness: Comprehension." (This including the process of integration of multiple pieces of information and determining if they are of relevance to the navigator.), 84% or 37 people answered “Strongly agree” or “Agree”.

As a supporting question, Question 2 with statement: "I believe that Augmented Reality (AR) projections help the bridge team to better follow & process information such as courses, cross-track distances (XTD) and ship speeds." (Level 2 Situation Awareness: Comprehension), was answered with 80% or 35 answering “Strongly agree” or “Agree”.

Level 3 SA: Projection

The next extract explains the weight of experience and its connection to working memory in older adults relating to level 3 SA:

> “…it might be hypothesized that age differences in the inferences will be minimal in situations where individuals can tap into well-developed knowledge structures

> established through extensive experience in a domain (e.g., elements A and B have always been associated with outcome X). When such knowledge is not available and inference generation must proceed in a more bottom-up fashion, then age differences might be more prevalent due to the increased demands on working memory processes. Also note that the projection accuracy is only as good as the information used in that process (e.g. the level 2 SA). Thus, any age-related processes that affect the amount and quality of information contained in working memory may negatively impact Stage 3." (Bolstad and Hess)

To Question 1c related to level 3 SA: Projection, 88% or 38 out of 44 people answered that they "Strongly agree" or "Agree" with the statement: "I believe that Augmented Reality (AR) projections help the bridge team in Level 3 Situation Awareness: Projection." (The ability to forecast future situation events and dynamics.).

The information stated in "Situation Awareness and Aging" by Bolstad and Hess although it cannot be used to generalize all individuals and situations with relation to aging and cognition, it is in line with previous research on SA and aging.

Worth mentioning is that by looking at the graph for Question 4 (with spread answers) we can notice that 94.6% answered affirming at least one of the statements: "mental processing becoming easier", "better time effective decisions" and "better quality decisions" that are regarding cognition in level 2 SA: Comprehension and therefore also level 3 SA: Projection.

6 Conclusions

As mentioned at the beginning of the thesis, human error constitutes the highest cause for accidents. Ranking high after weather, are collision and grounding which are linked to a lack of situational awareness.

This lack of situation awareness might deteriorate with the increase of worldwide ship traffic which adds to the strains already experienced by the OOW due to the general worldwide reduction of on-board crew.

The clear benefit of Augmented Reality projections to marine navigation is perhaps the enhancements to level 1 Situation Awareness: Perception (Endsley, 2000, p. 5) (In this study, it is mentioned that 76% of SA errors in pilots could be traced to problems in the perception of needed information). The projections provided by AR would substantially enable the Officer of the Watch to perceive more information from the environment and therefore question the correctness of a situation. An example to this being the ability by the OOW on board, to check "on the go" that a buoy has drifted away from its original position.

Another area worth mentioning is the possible reduction in distractions that affect the attention of the OOW. As discussed above, attention has an impact on performance. Augmented Reality could be able to help the OOW get less distracted and focus more on the happenings outside the window. As the time spent "head-down" would be greatly reduced.

As seen from studies mentioned above, working memory tends to have a decline in ages from 50 to 80 years (considering that 50 to 65 year olds are in working age). Reducing the brain capacity to deal with situations on board that take a strain on the OOW. Therefore a moderation of such workload might prove helpful. This easing could be provided by Augmented Reality projections in marine navigation.

Given these points, although ship navigation assisted by AR seems to indicate that there are advantages on its use, such as in poor visibility or open sea scenarios, empirical tests showing the benefits and practicality of its usage on-board are needed. Apart from this, research and authorization by the maritime legislating bodies will be needed as well.

6.1.1 Research question

Answering the research question: “Can Augmented Reality be helpful in building up Situation Awareness (SA) in marine navigation?” has proved to be an arduous task that cannot be simply answered by making a literature-based analysis and a questionnaire.

Despite of this, having reviewed various literature sources in books and internet articles and publications, peer conversations and a questionnaire, they all seem to incline to the benefit of AR to assist marine navigation. Therefore, if forced to give an answer to the question, I say that it will only be possible to answer when the actual benefits are tested empirically in ships or simulators. Moreover and of great importance, is to understand that not all and any AR projections could be helpful to building up Situation Awareness on board.

The question must be transferred to a specific operating system for evaluation to observe if it is actually of help to the navigator.

6.1.2 Limitations

Although the study presented has been attentively attended to, there are limitations.

Firstly, there is a limitation on the thesis questionnaire use due to the restricted population size. The restricted population size is due to the complexity and novelty of the topics of Situation Awareness and Augmented Reality as well as to the time permitted to answer the thesis questionnaire, which was two weeks. Conversely, the number of answers received, 44, suggests that the answers are honest and valid due to the length of the text in Appendix I which was necessary to be read before starting the questionnaire.

Another limitation related to the validity of the thesis questionnaire is the fact that the results are not empirical. To be able to empirically evaluate the impact of Augmented Reality on Situation Awareness, we would need to test its use directly on ships at sea or simulators.

Lastly, and worth mentioning is the limitation on the depth of knowledge to the complexities of Situation Awareness and Augmented Reality systems. Although familiarization and analysis on the topics related has been made, it cannot match the knowledge of dedicated professionals in the areas of human cognition and Augmented Reality technology.

6.1.3 Further Research

Further research on the topics of Augmented Reality and ship navigation as related to Situation Awareness is being conducted by Mr. Stephan Procee from the maritime institute Willem Barentsz, in The Nederlands. His work pursues to empirically demonstrate the benefits of AR to marine navigation.

In connection to the research question, the next step forward would be the creation of such operating system for use on board and in simulators to make an assessment of its aid.

7 Acknowledgements

I would like to specially thank Mr. Stephan Procee from the Maritime Institute Willem Barentsz, whose guidance and discussion on the topics of Situation Awareness and Augmented Reality in the maritime environment, was invaluable. I am grateful to him for sharing his expertise and encouragement for this research.

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Appendices I, II & III

Appendix I

Experiment visualization & scenario layouts

Introduction

The main goal of the visualizations presented in this paper is to look for the Situation Awareness (SA) improvements in the performance of the Officer of the Watch (OOW) when implementing Augmented Reality (AR) to ship navigation.

In order to perceive the hypothesized differences between conventional navigation (without the use of AR) and with AR usage, the scenarios that are presented here will be described and explained to the best abilities in such way that the reader, coming from a maritime background, could feel present in such situation at sea.

It is due to the complexity of the software, the subsequent integration on simulators, the need of Head Mounted Devices (HMDs), availability of subjects, and other minor technical difficulties that the testing on simulators or at sea is a challenging task. But it will nonetheless be carried out in the near future to empirically assess the benefits of AR implementation into marine navigation.

For the meanings of abbreviation & special terminology, please refer to the glossary section at the end of this paper.

Experiment visualization set up

It is to be noted that the described scenarios are not tested physically, on a simulator or at open sea. Instead, the scenarios are hypothesized in a way the reader will be able to understand the importance of such software in marine navigation and consequently create an opinion and evaluate the use and implementation of AR to navigation.

The scenarios that have been selected for these visualizations are those that due to the projections granted by AR, seemed to give the most evident contrasts between the two navigation approaches (Conventional and Augmented Reality approaches). These situations mainly comprise the regular tasks of OOWs including conning and monitoring with different set-ups.

Usage of HMDs

As presented in the thesis, the HMD used by the OOW is no different in functionalities and purpose from other HMDs used for videogames, course training, etc.

Figure 13: HMD use tested in Terschelling's Willem Barentsz Maritime School, The Netherlands (ACCSEAS , n.d.)

In the above figure, the HMD similarly to conventional eyeglasses, consists of lenses. Into these lenses is projected the video feed of augmented objects with a set transparency that does not impede the ability of the user to see through it. Thus, overlaying the real & projected sight.

The HMD projection of objects, in a sense following the Integrated Navigation System (INS) principle would be fed by the inputs of the different bridge navigation resources such as Automatic Identification System (AIS), Radio Detection and Ranging (RADAR), Automatic

Radar Plotting Aid (ARPA), Electronic Chart Display and Information System (ECDIS), Gyro Compass, Magnetic Compass, among others.

Another implementation of which this new way would be beneficial is the usage of user charts. Where the OOW could input caution areas, no-go areas, Marine Protected Areas (MPAs), environmentally sensitive areas with regards to ballast, sewage, graywater and other discharges. As well as ship/company specific procedures.

Perhaps the most evident benefit is the projection of the known "Simulated track prediction". This prediction tool unlike its predecessor the "Path prediction" (which integrated simplified motion models), would give the navigator a direct view of the ship's movement and path with the current rudder and speed orders.

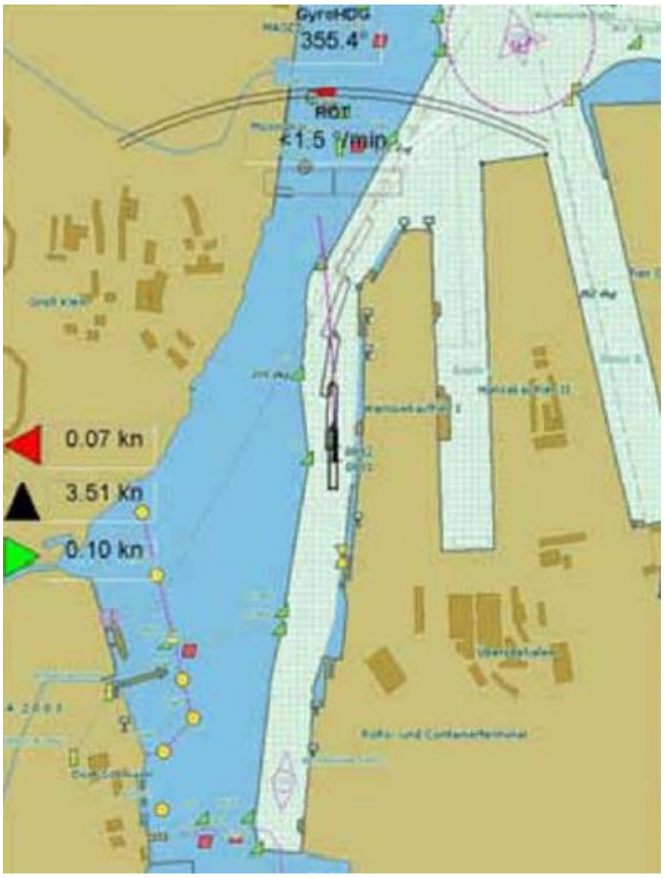

Figure 14: Maneuvering prediction displayed on ECDIS (Benedict, et al., 2010)

As it might seem noticeable to the reader, AR projection onto HMDs is appealing as most information is readily available & collected into one system thus allowing the bridge team to spend more time looking out the windows than down into the bridge's scattered resources.

With regards to the projected objects, they would be so called “locked” to their relative position to the ship on the chart as shown on the figures below.

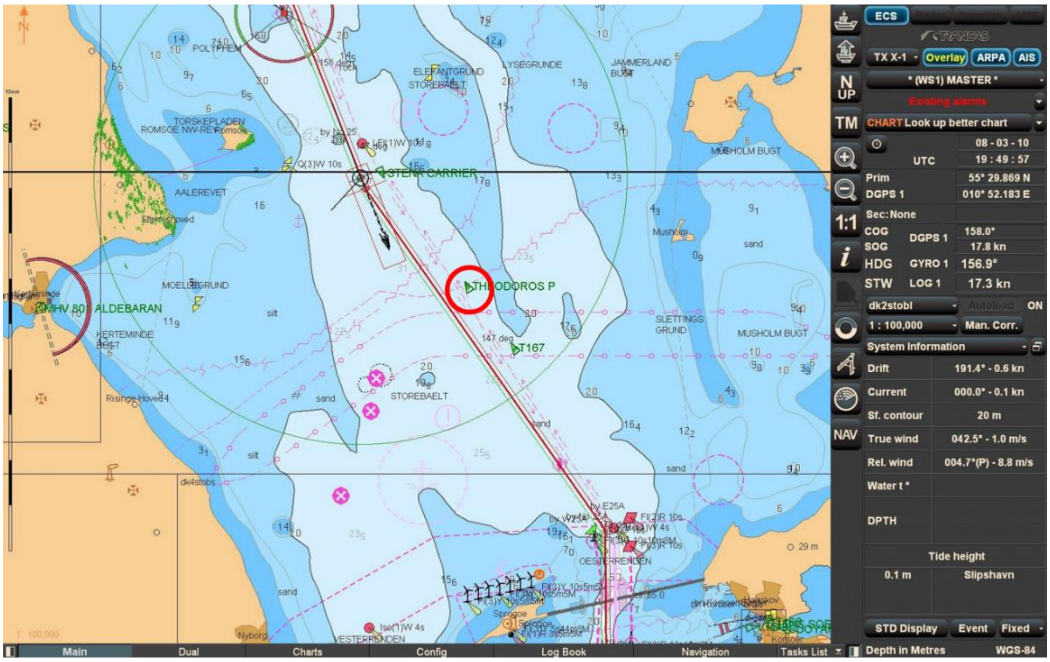

Figure 15: Target displayed on ECDIS (Expo, n.d.)

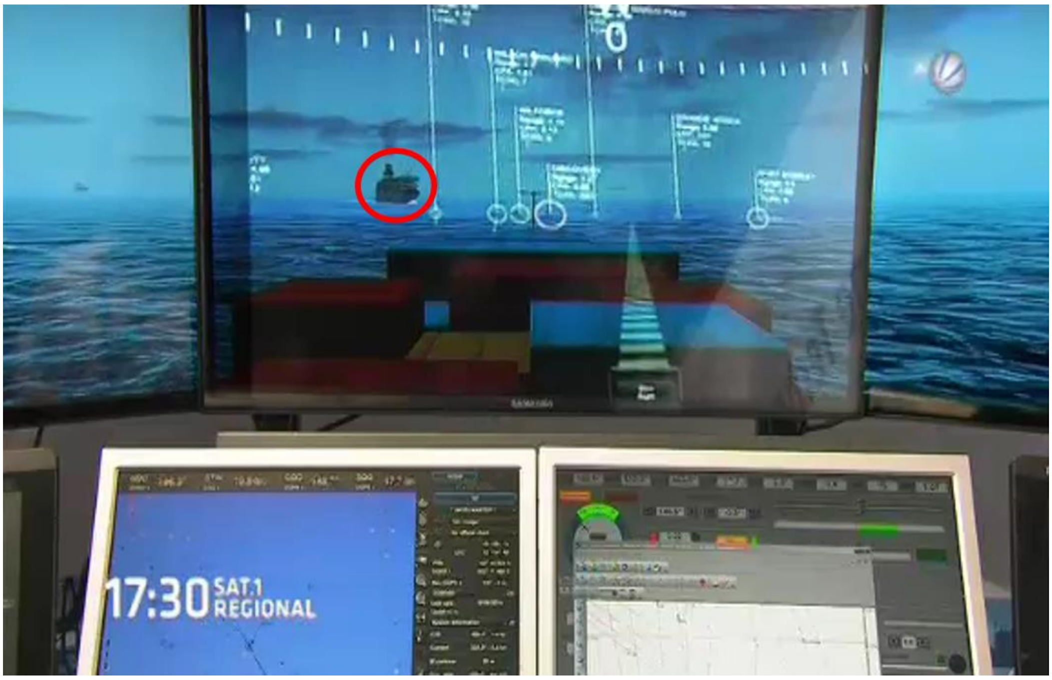

Figure 16: Same ship visualized through AR projections (ACCSEAS, n.d.)

Figure 17: Example of final outside view through AR projections (de Vlaming, et al., 2013) .

Scenarios & Setting

As explained earlier, the scenarios are of a regular nature of work for the ship navigator. Special attention has been put into trying to simplify the scenarios in order to ease the reader's visualization while still making it possible to draw conclusions from the different types of approaches. The Conventional and AR approaches.

Ship type details

In order to express the ample span of tasks to which a bridge team is presented with, the model ship chosen is a cruise ship. The cruise ship is a mega sized ship with 1500+ sleeping rooms. The regular traffic of the ship are the Caribbean and Mediterranean Seas and Atlantic Ocean. As common with these types of ships, they contain big sized ballast, black, gray, etc. tanks to temporarily store these substances before being able to discharge the tanks in permitted areas at controlled and monitored discharge rates.

Scenario 1: Entry to enclosed waters

Description

The vessel is underway entering an enclosed waters area, which is considered to be of high risk for the safety of the vessel. Although this part of the voyage has been prepared for by the bridge crew, the grounding line now lies within 3 NM or 20 minutes forward of both beams. The ship speed is reduced and additional resources are called to the bridge accordingly.

Conventional approach

After receiving the additional resources to the bridge, the bridge team has assignments to each person to cover all areas of the task ahead. This bridge team receives information coming from the outside view (out the window), RADAR, ECDIS, Echo sounders, etc. The team’s positive resolution is to a high degree motivated by the sufficiency of communication among bridge members so that all share the same mental picture and follow the same procedure.

AR approach

On receipt of the additional resources to the bridge, aided by the communication among the bridge team as well as the projections that are presented to them by the HMDs, they are able to monitor the ship’s transit in its full characteristics while looking out the window. These have been inputted through the bridge electronic chart system and user charts to indicate any special boundaries, landmarks, shallow areas and any other relevant information.

Conclusion

Thanks to the projections on the HMDs the bridge team is able to be more accurate in decision making and make time effective monitoring as it does not need to check between screen and outside world. This allowing them to increase their focus on the maneuvering of the ship, ship motion and collision avoidance.

Scenario 2: Entry to bad visibility, enclosed/restricted waters & high traffic

Description

The ship is underway in open waters, light traffic and unlimited visibility. The bridge team, consisting of 2 Bridge Officers and a look-out, has been monitoring the forecasted weather and they are expecting to enter into a patch of dense fog (cloud scale 9) at the arrival to an area with high traffic and enclosed/restricted waters.

Conventional approach

Under these circumstances, the ship's company procedure states that the bridge resources are increased and that the ship elevate the risk factor to red (the highest level).

And so, on arrival to the bad weather area the bridge team consists of 2 Senior Bridge Officers, 2 Bridge Officers and 2 ABs. Under the company policy the navigation tasks are divided into conning, monitoring, collision avoidance, look-out, etc. Apart from the special conditions due to the situation, the bridge team needs to take care of any stability operations in the background (heeling, stabilizer or ballast) and environmental procedures among others. Although these seem to be an arduous and stressful task it is facilitated by the use of bad weather checklists.

Communication for updates, overall perception and keeping a same mental picture within the team is determinant to the positive outcome of the situation.

AR approach

Besides the above-mentioned procedures, the projections granted by an HMD give the bridge team a visual location of relevant information without delay. They are able to see out the window the markings that have been earlier inputted to show a speed reduction, point of no return, boundaries, etc. As well as the location of other ships thanks to the augmented projections by the HMD.

Conclusion

As it is understandable, any bridge officer would feel uneasy, overwhelmed and perhaps stressed if they were to find themselves in the situation presented in this scenario. The question "What if?" would keep coming to one's head.

Not to say that this question would not appear in the officer's head that follows the AR approach, but it is agreeable that there would be an increase in confidence towards the actions taken when the team is able to make decisions while looking out the window and confirming these with other navigation equipment in the conventional way.

The AR approach, substantially benefitted by a proper voyage planning would be able to display vessels, vessel speed readings and vectors, boundaries, points of no return, emergency anchorages, etc. All these serving to alleviate the pressure and optimizing the amount of time used to make a decision.

Scenario 3: Environmental boundaries

Description

The ship is underway in the middle of the night and the bridge team has recently changed the OOW. The change of watch happened prior to the entry into an environmental area with restrictions.

The area B consists of the environmentally protected area intended to enter and area A, which the ship transits at the moment is the unrestricted one.

While on area A, the ship is allowed to discharge into the sea and atmosphere substances "x", "y" and "z" as the ship is more than 12 NM from the nearest land.

At area B, the ship is allowed to continue discharge of substance "y" but the rest must be stopped before entering in such area.

Conventional approach

The OOW as regular procedure, makes sure to communicate with the Engine department for the timing of closure of the discharge valves, flashing, etc. He/she is monitoring the time available for discharge on the Electronic Chart Display before reaching the environmental boundary. This task is arduous adding to it the vicinity of other ships and changes of speed which affect the time of arrival at the environmental boundary. Moreover, it is prudent to give ample time for the engine department to close the valves in case there were any malfunctions.

AR approach

As the OOW transits area A, the HMD is able to project the constantly changing time of arrival at the environmental boundary as well as seeing visually out the window the boundary itself provided it has been inputted to the system.

Conclusion

As in this case the environmentally delicate moment happens in the middle of the night, it can be expected that the ship personnel, adding to the nature of ship work, would suffer of fatigue, tiredness, etc. that can only worsen their abilities.

Adding to this are the pressures by the company to reduce time and expenses spent at harbor to discharge substances that could be discharged at sea. This pressure pushes the OOW to try to make the gap between closure of valves and entry into environmentally restricted areas as short as possible. In relation to this and adding onto the workload is the requisite to keep good stability for the ship, which changes due to the discharges.

A reduction on workload and stress, assumed by following the AR approach, can only help in reducing the energy and time strains thus allowing a better working memory by the OOW (Endsley, n.d., p. 12).

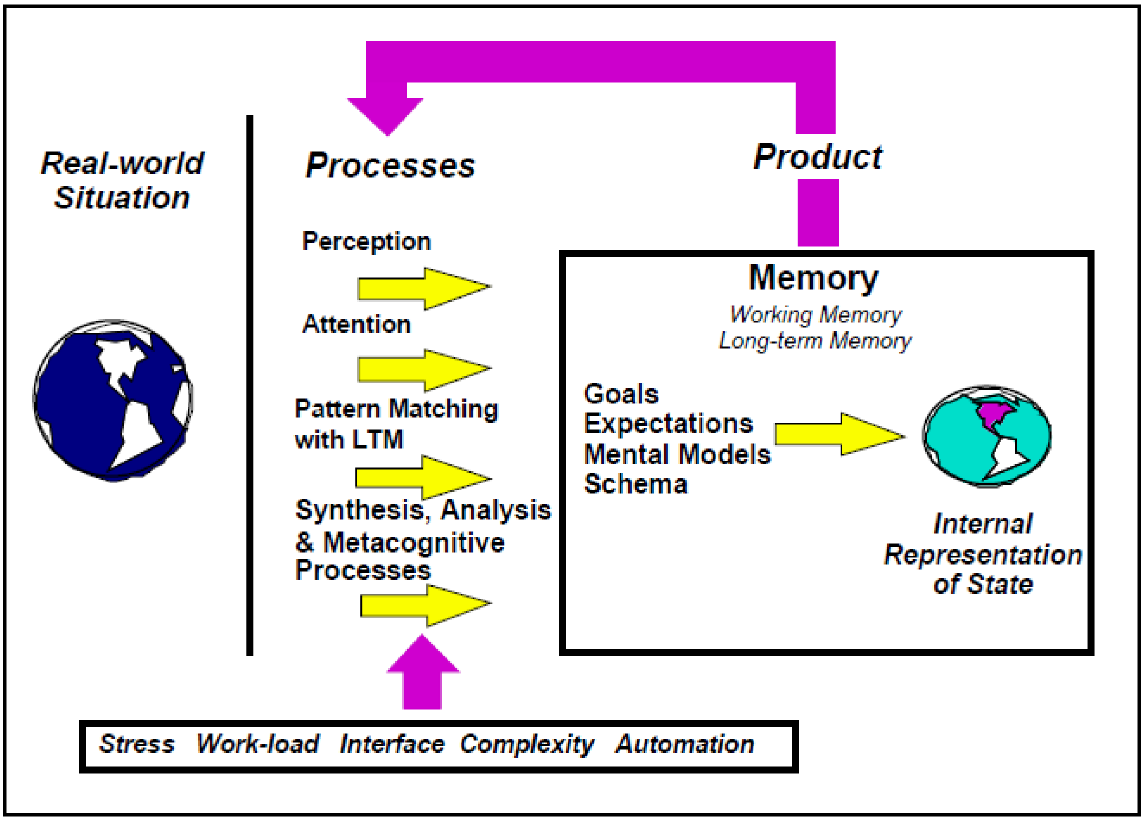

Figure 18: Mechanisms and processes involved in SA (Endsley, n.d., p. 13).

Scenario 4: Anchoring

Description

The ship is approaching an anchorage position and will drop anchor at a known area with defined distances to the grounding lines. The weather at arrival is good and visibility is unlimited but as seen from the forecast, it is expected to change abruptly after a few hours. Anchor watch will therefore be an important task to monitor anchor drag.

Conventional approach

As per company policy the bridge team after completing the pre-arrival proceedings and reducing speed, approaches the position to drop anchor guided by the ECDIS or RADAR displays. When they arrive at the designated anchorage position they proceed to drop anchor and monitor that the ship is not dragging the anchor. They as well make sure to let out enough chain length to permit for the upcoming weather.

On arrival of the bad weather, the bridge team risk factor is elevated due to the distance to the grounding line.

Monitoring for anchor drag visually (bearings and ranges to land marks) and other navigation equipment, as well as making engines ready is a prudent precaution to be followed as per the company's bad weather checklist.

AR approach

On arrival to the anchor area, thanks to the projections provided by the AR system the bridge team is able to have a better idea of the precise position for anchoring.

After anchoring is completed and precautious measures for the upcoming weather are taken, augmented projections for bearings and distances to landmarks are inputted and therefore visible at a glance out the window (including readings of such values). Apart from this, shallow areas which are associated with the ship specifics (marked by color coded projections on the surface of the water) are easily noticeable to keep away of.

Conclusion

Under all the stress that comes from these type of maneuvers, the increase in confidence that the AR approach sustains is appreciable. It gives the navigator the chance to increase his/her focus on monitoring but also allows for a better understanding of the ship's motion. Meaning that as the anchorage position becomes visually perceivable by looking out the window, there are benefits to the outcomes as the mental calculations and predictions are "optimized". Thus, increasing the level 3 SA, the projection outcome (Endsley, n.d., p. 7).

Glossary & Special terms

AB: Able Seaman.

AR: Augmented Reality.

ARPA: Automatic Radar Plotting Aid.

Collision Avoidance: The Officer assigned Collision Avoidance provides collision avoidance data and recommendations to the Conning Officer.

Conn: To have actual control of the ship's motion, including giving course, helm and engine orders.

Navigational Command: To be on the Bridge and have overall responsibility for the safe navigation/manoeuvring of the ship.

ECDIS: Electronic Chart Display and Information System.

Enclosed waters: Grounding line is within 3 NM of both beams.

Grounding line: The depth of water where the vessel's hull will ground (touch).

HMD: Head-mounted Display.

INS: Integrated Navigation System.

Monitoring: Monitor the actions and orders of the Conning Officer in order to provide a two-person check that the orders are given and followed correctly.

MPA: Marine Protected Area.

NM: Nautical Miles.

OOW: Officer of the Watch.

Open waters: At sea when not enclosed by land, ice, or other barriers.

Point of no-return: Is the point after which there is no sea room to turn the vessel and return back.

RADAR: RAdio Detection And Ranging.

Unlimited visibility: Normal, good visibility condition

Situation Awareness (SA): Knowing what is going on around you (Endsley, n.d., p. 5).

Level 1 SA (Perception): Perception of cues (Endsley, n.d., p. 5).

Level 2 SA (Comprehension): Apart of perceiving and attending to information, it includes the integration of multiple pieces of information and a determination of their relevance to the person’s goals (Endsley, n.d., p. 7).

Level 3 SA (Projection): This is the highest level of SA, the ability to forecast future situations and events (Endsley, n.d., p. 7).

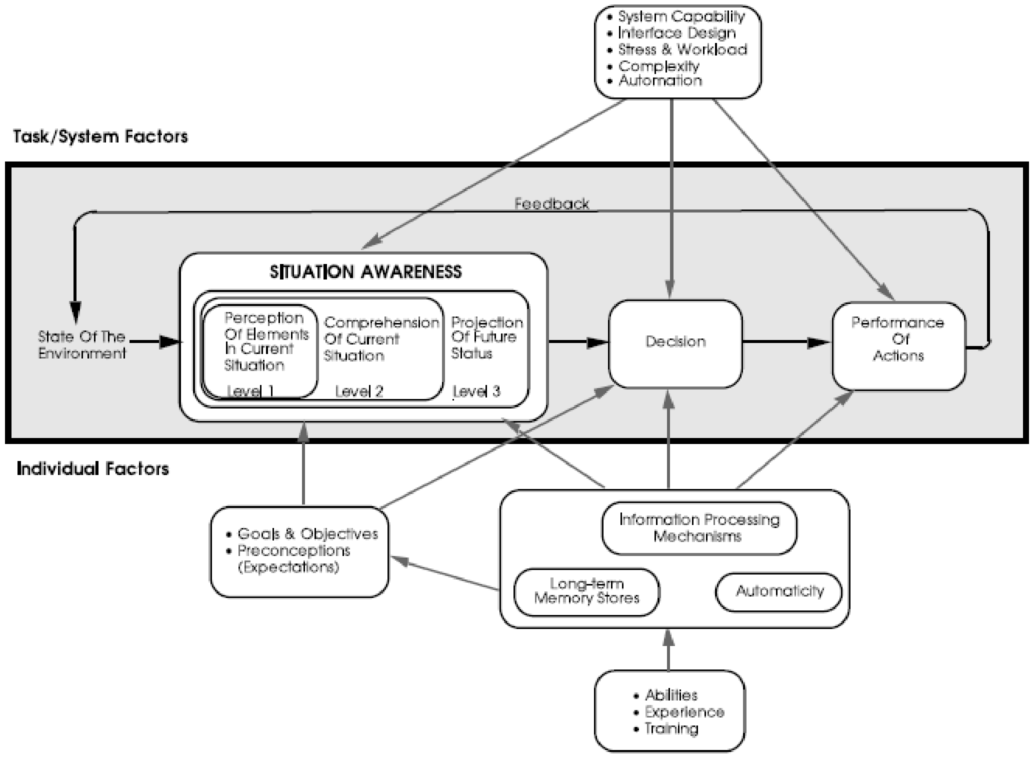

Figure 19: Model of SA in dynamic decision making (Endsley, n.d., p. 6).

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Appendix II

Thesis Questionnaire: "Situation Awareness Improvements by Augmented Reality Implementation"

Thank you for agreeing to take part in this questionnaire intended to explore the gains of augmented reality to marine navigation. The survey itself, having read through Appendix I of my Thesis, should take 3-5 minutes of your time. If you have not read through it, please do and enter into the lottery of a 40€ amazon gift card to be raffled among the respondents.

Please to view Appendix I, click on the link below or copy the URL:

https://drive.google.com/open?id=1fPA7ZJTFhEIxdJDYxs0_FCs8wVsNy8Wh

Here is an introductory video on future use of augmented reality in aviation:
https://www.youtube.com/watch?v=E0UZWn4bnGY&t=5s

Thesis Questionnaire: Appendix II

The visualizations exposed in Appendix I, are idyllic cases in which the main focus is to create dialogue and subsequently take steps to conclude if there are any improvements to safety by the implementation of Augmented Reality (AR) to marine navigation.

As the concept of AR implementation with regards to the marine sector still lays in the basic state, this research is intended to look at the practicality and feasibility of such system.

This Questionnaire

With the purpose of receiving valuable answers, it is kindly asked that every response to the questionnaire is given honestly with thought and is derived from maritime background experience.

It's worth mentioning that the use of the information disclosed by the respondent will be solely used for the research purposes of the Thesis: "Situation Awareness (SA) Improvements by Augmented Reality (AR) Implementation" by Kamel Kalmoni, and will be treated anonymously in line with data protection acts.

Question 1a

Please indicate how strongly you agree or disagree with the statement below by selecting from Strongly disagree to Strongly agree or N/A.

If in addition to one of the options below you would like to explain why, click "Other" and include which option by writing for example: "Neutral, because..."

Statement: *"I believe that Augmented Reality (AR) projections help the bridge team to better notice buoys, light houses and other landmarks."*

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. N/A (Question not understood)
7. Other…

Question 1b

Watching the video below, please indicate how strongly you agree or disagree with the statement.

Statement: *"I believe that Augmented Reality (AR) projections help the bridge team in Level 2 Situation Awareness: Comprehension."* (This including the process of integration of multiple pieces of information and determining if they are of relevance to the navigator.)

https://youtu.be/B_bjlp5kIZY

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. N/A (Question not understood)
7. Other…

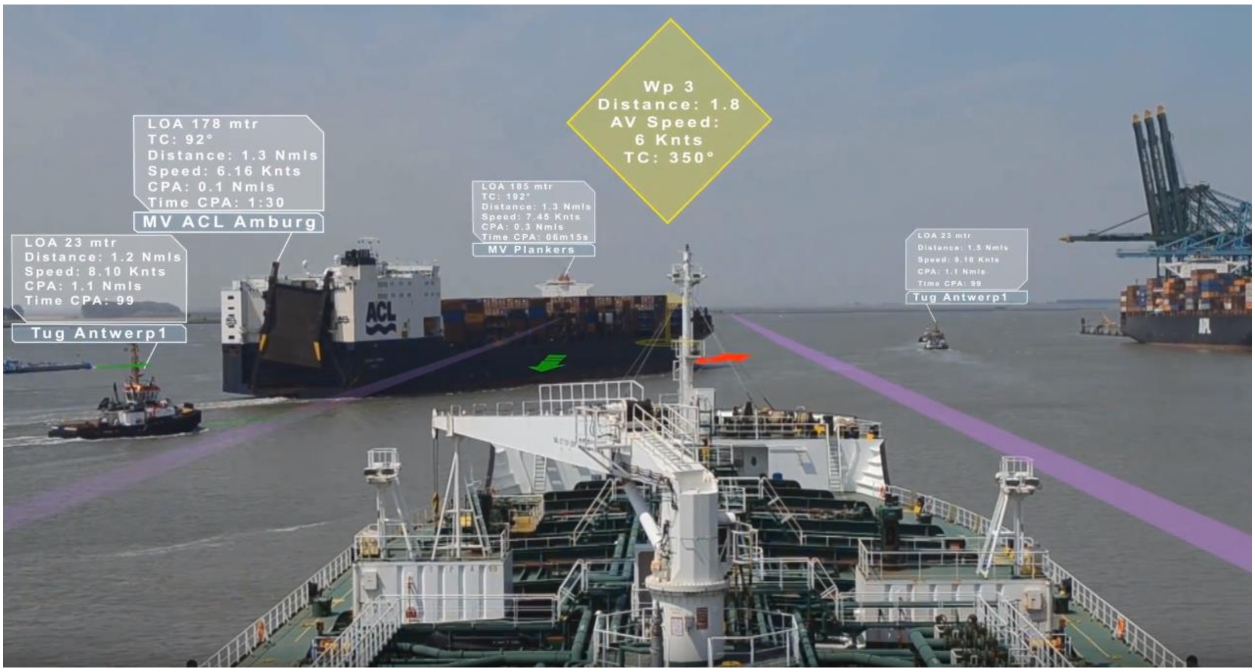
Question 1c

Statement: *"I believe that Augmented Reality (AR) projections help the bridge team in Level 3 Situation Awareness: Projection."* (The ability to forecast future situation events and dynamics.)

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. N/A (Question not understood)
7. Other…

Question 2

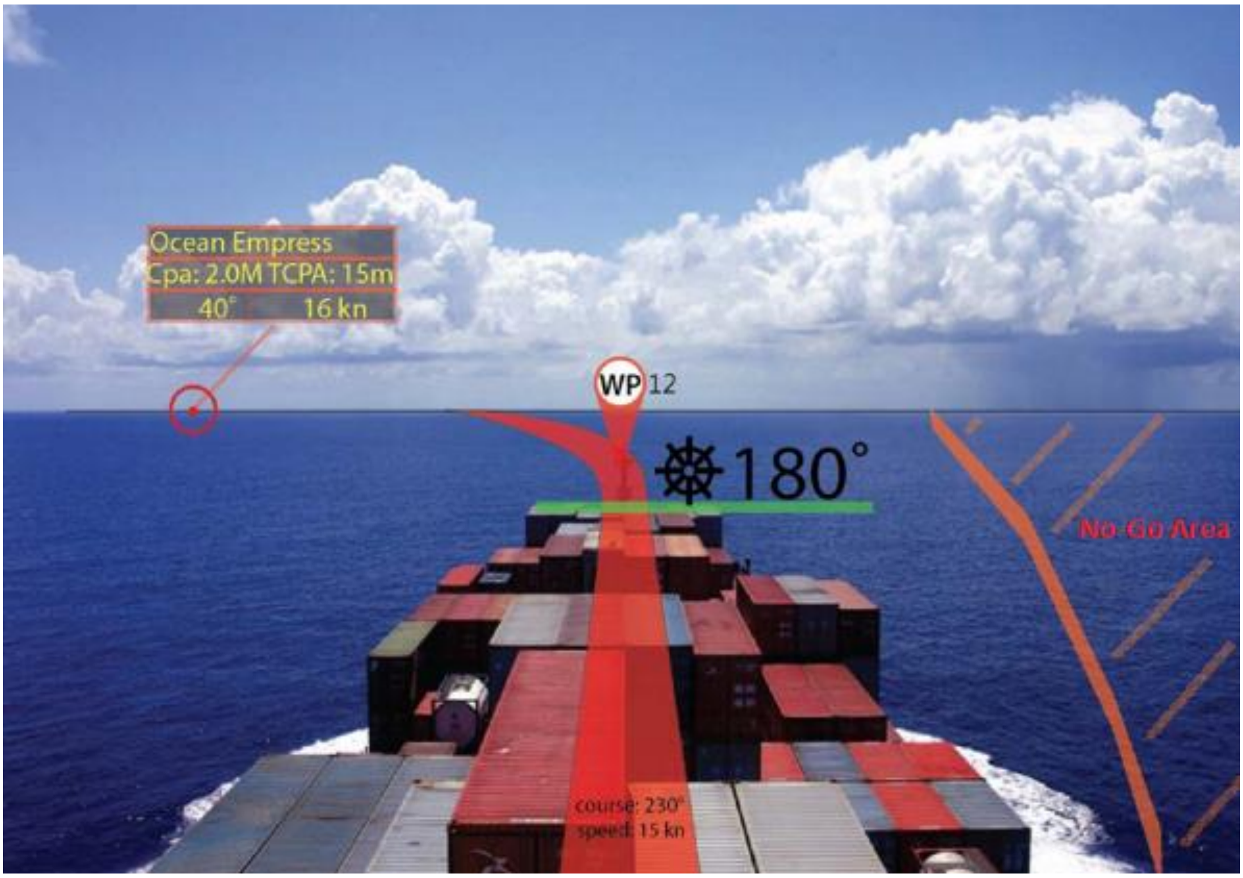
Statement: *"I believe that Augmented Reality (AR) projections help the bridge team to better follow & process information such as courses, cross-track distances (XTD) and ship speeds."* (Level 2 Situation Awareness: Comprehension).



1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. N/A (Question not understood)
7. Other…

Question 3

Statement: *"I believe that Augmented Reality (AR) projections help the bridge team to better distinguish shallow/no-go areas."*



1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. N/A (Question not understood)
7. Other…

Question 4

Please choose from the following answers to complete the statement.

Statement: *"After training on the use of Augmented Reality in marine navigation, I believe that":*

1. “The mental processing needed to perform decision making will be easier.”’
2. “I will be able to make better time effective decisions.”
3. “I will be able to make better quality decisions.”
4. All of the above.
5. None of the above
6. N/A (Question not understood).
7. Other…

Question 5

Statement: *"After training on the use of Augmented Reality in marine navigation, I would feel confident to use this new approach to improve ship safety."*

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. N/A (Question not understood)
7. Other…

Final question: Question 6

After going through the scenarios in Appendix I, and having reflected on the new possibilities of such new approach (Augmented Reality), describe your willingness to its implementation into marine navigation in order to improve Situation Awareness.

1. Strongly unwilling
2. Unwilling
3. Neutral
4. Willing
5. Strongly willing
6. Other

Lastly, what is your age and navigation experience on board merchant or sailing ships?

Navigation Experience

1. Under 1 Year
2. 1 – 2 Years

3. 2 – 5 Years
4. 5 – 10 Years
5. 10+ Years

Age

1. Under 18 Years
2. 18 – 24 Years
3. 25 – 34 Years
4. 45 – 54 Years
5. 55 – 65+ Years
6.

Thank you for completing the Thesis Questionnaire!

Thank you for taking the time to complete this questionnaire. I appreciate the information you have provided. The responses will contribute to my Thesis work and will be analyzed.

If you have any comments on the questionnaire or the Thesis work, please send an email to kamelkalmoni@gmail.com with subject COMMENT.

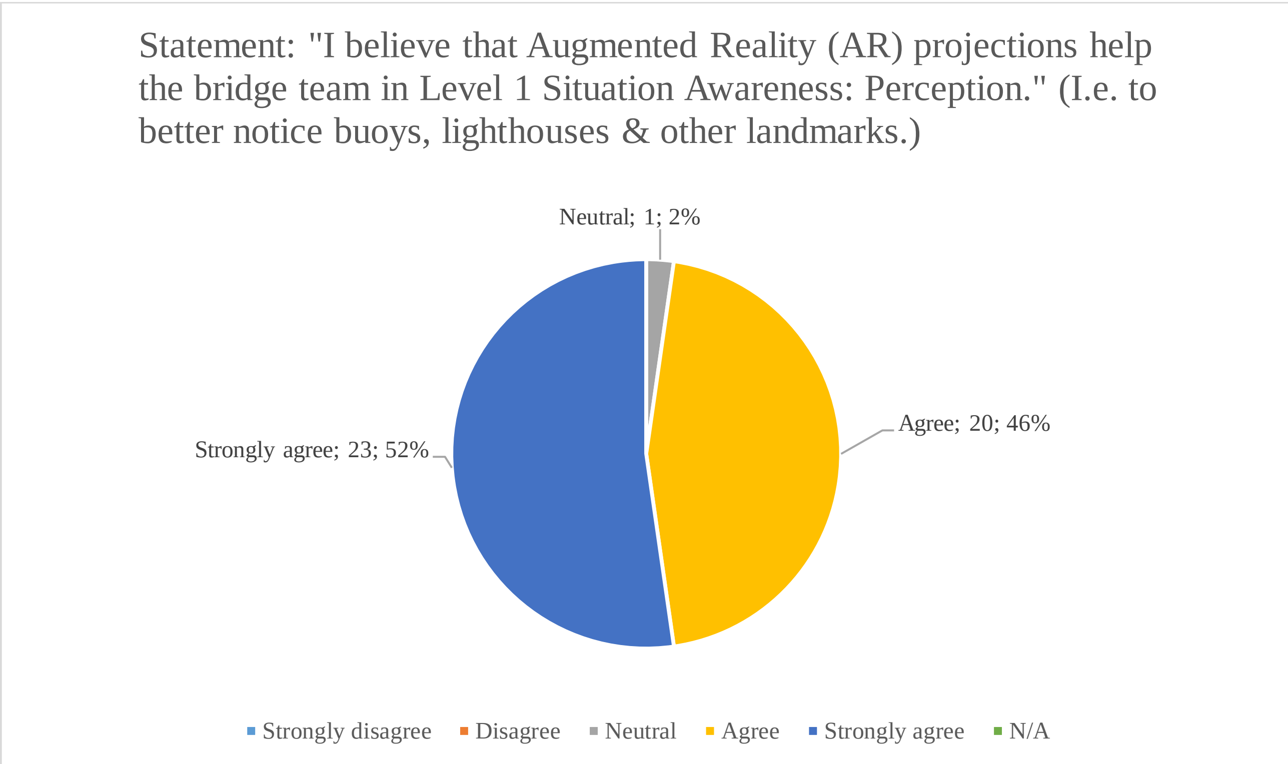
Regards,

Kamel Kalmoni

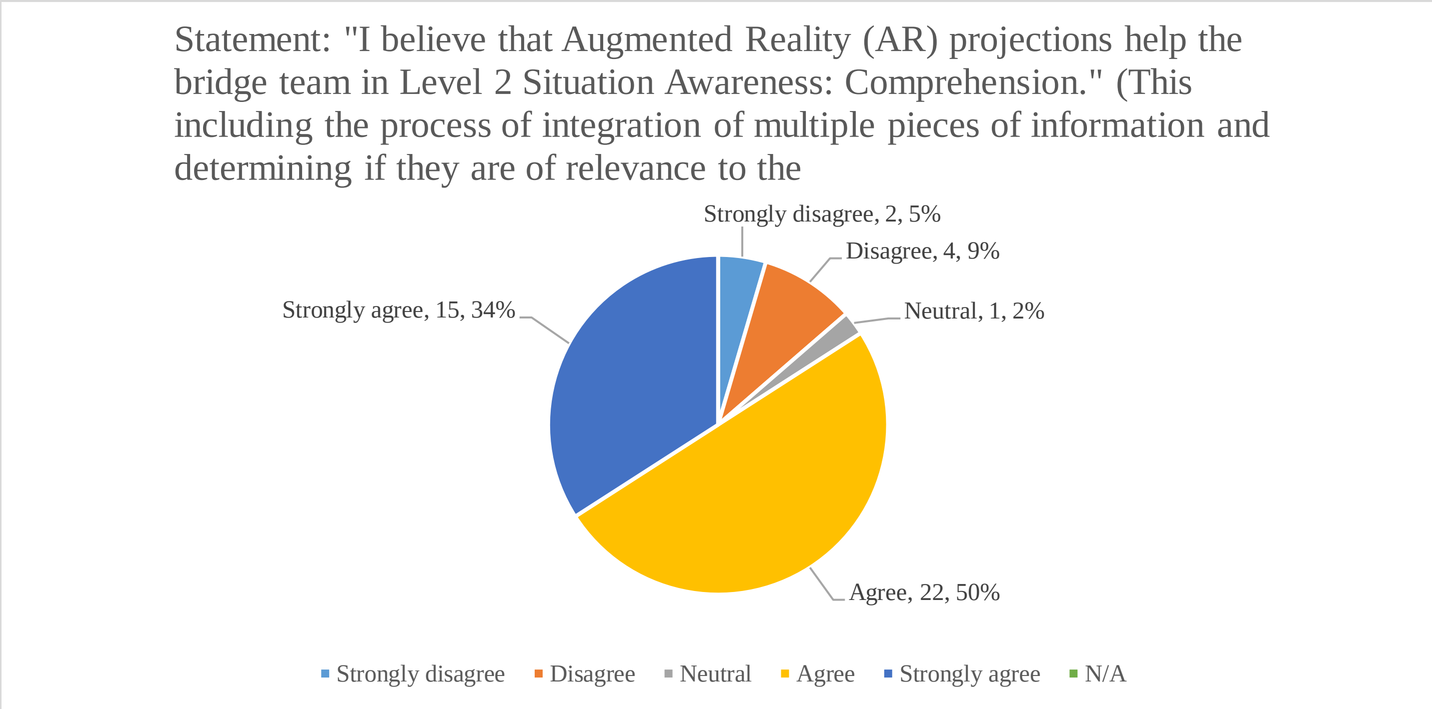
Appendix III

Thesis Questionnaire results: "Situation Awareness Improvements by Augmented Reality Implementation"

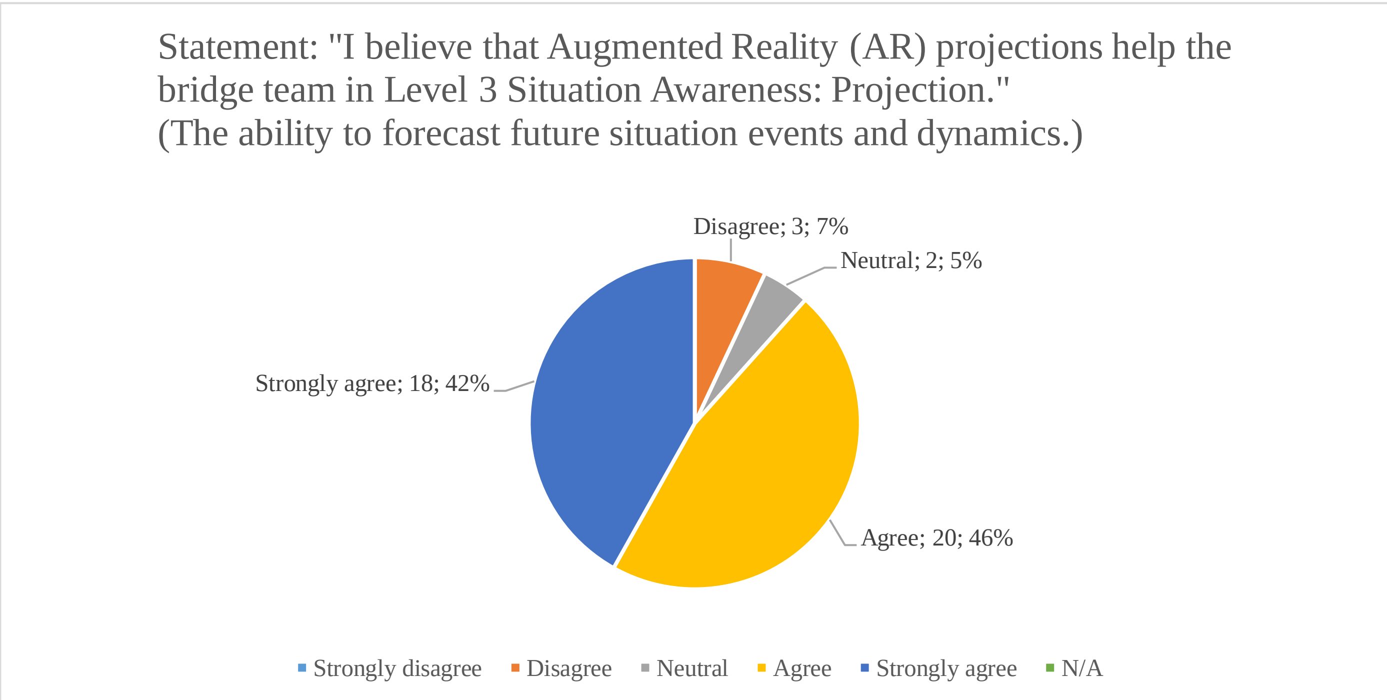
Question 1a



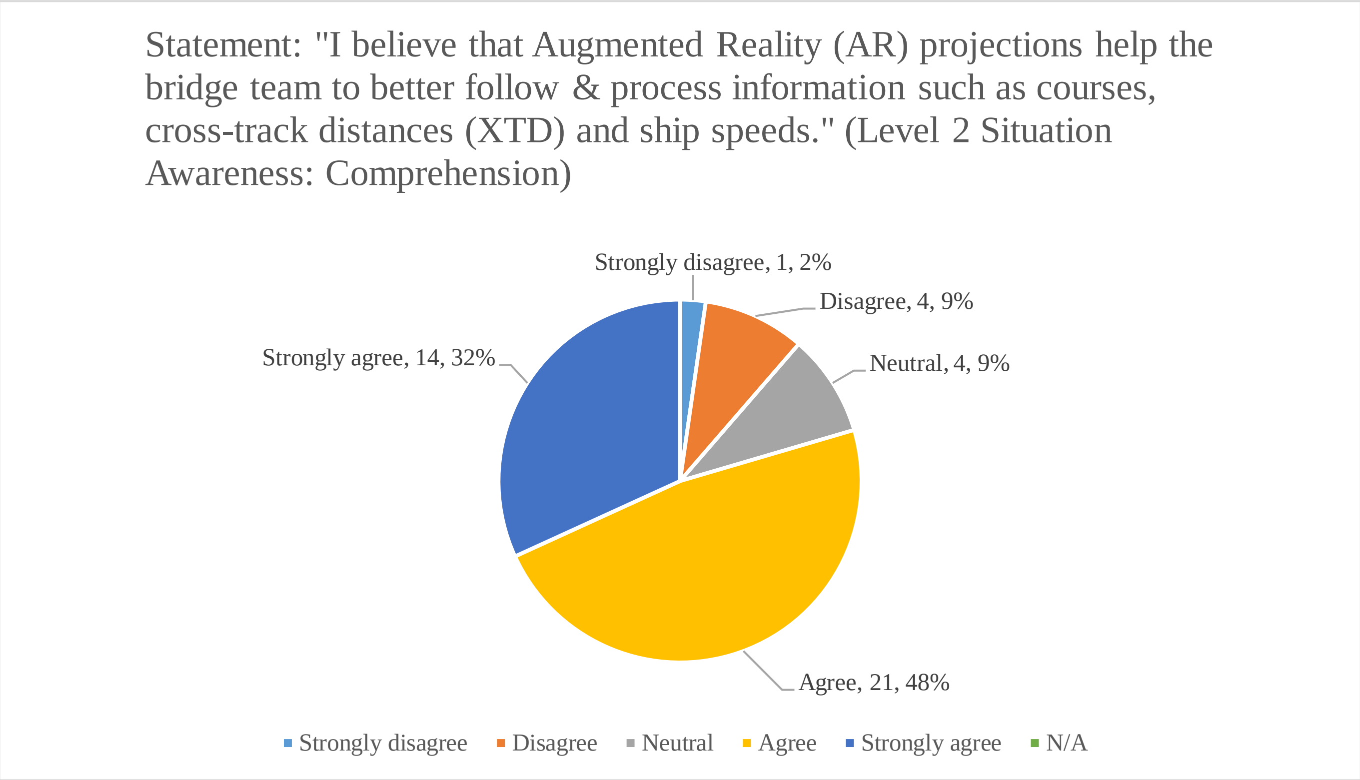
Question 1b



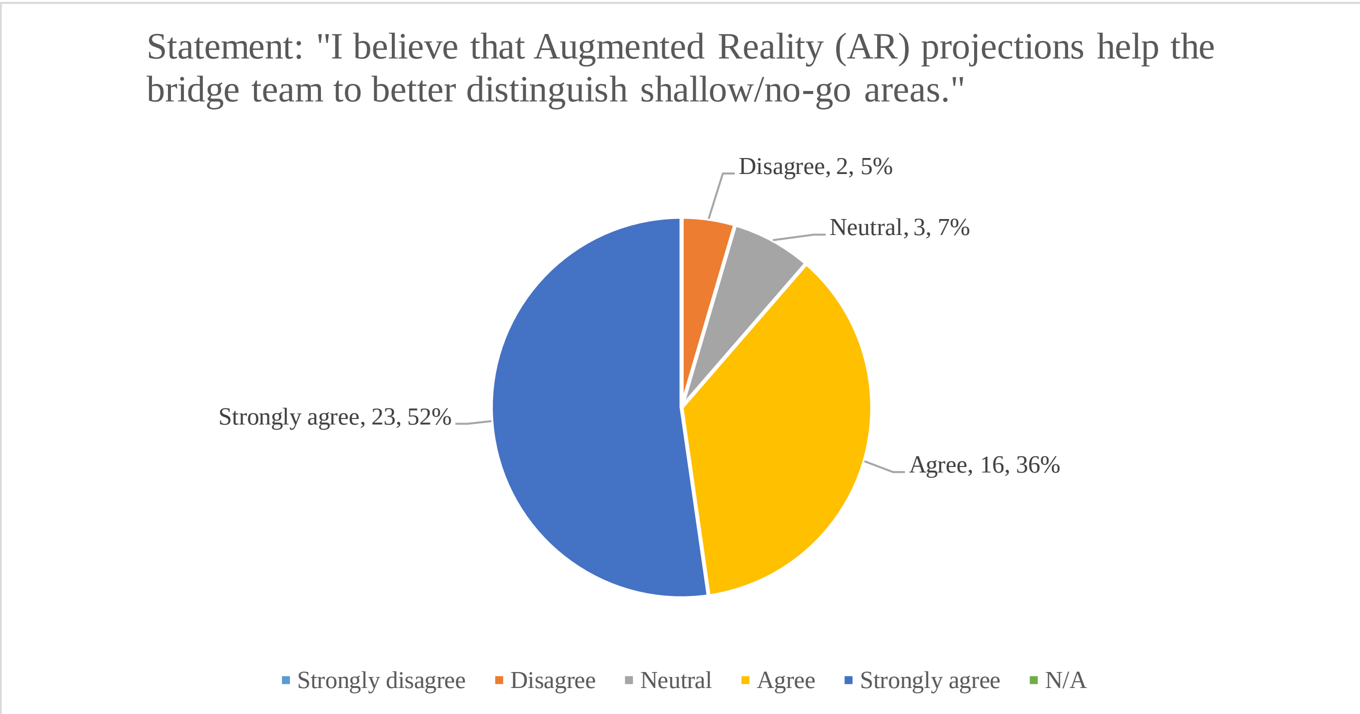
Question 1c



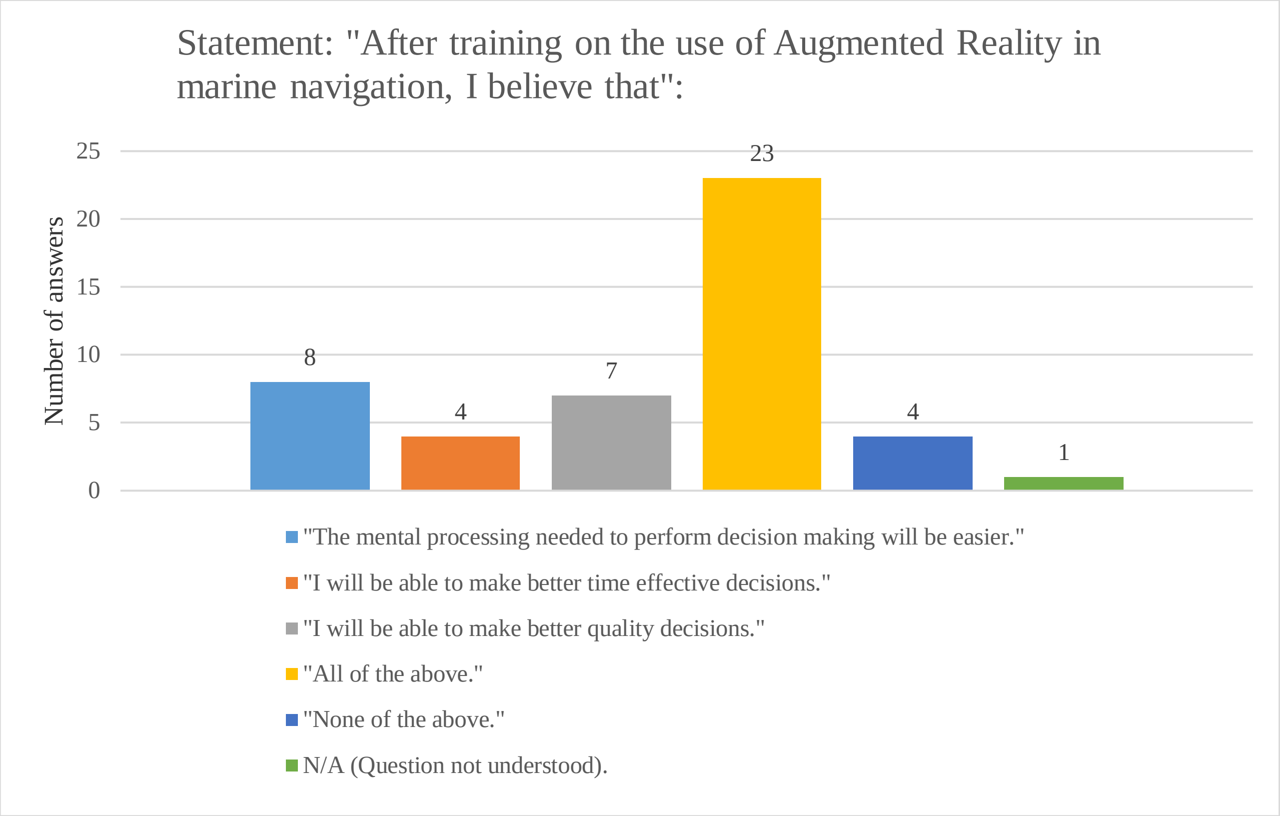
Question 2



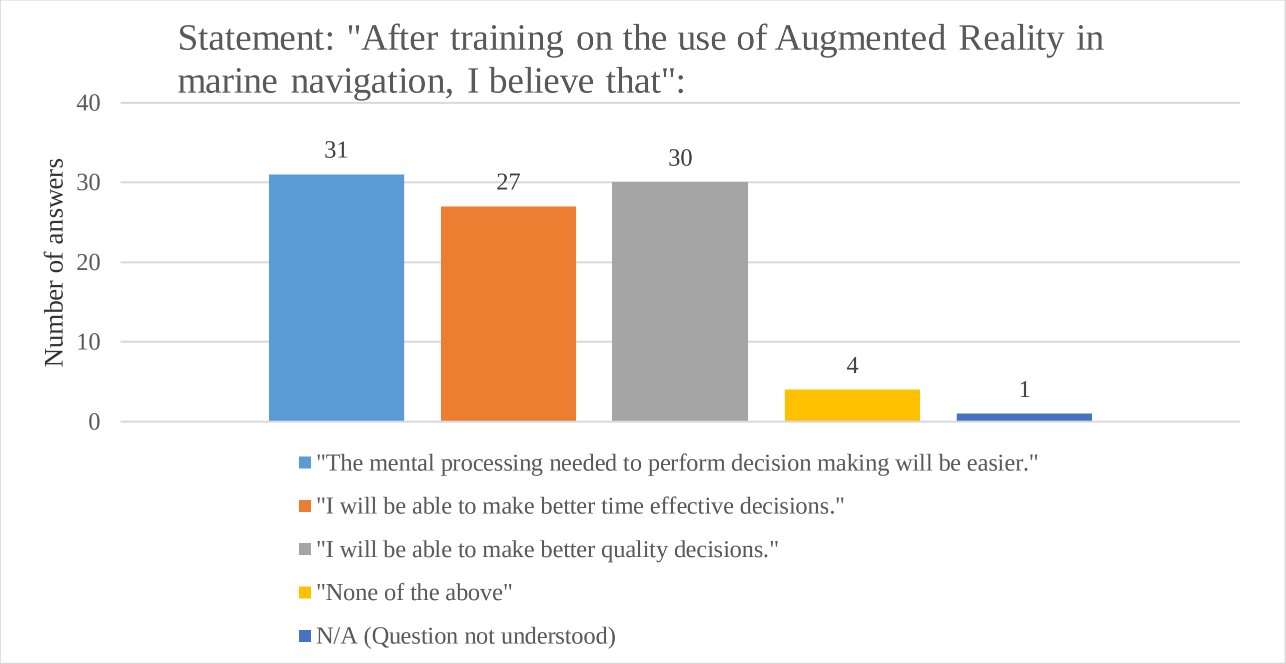
Question 3



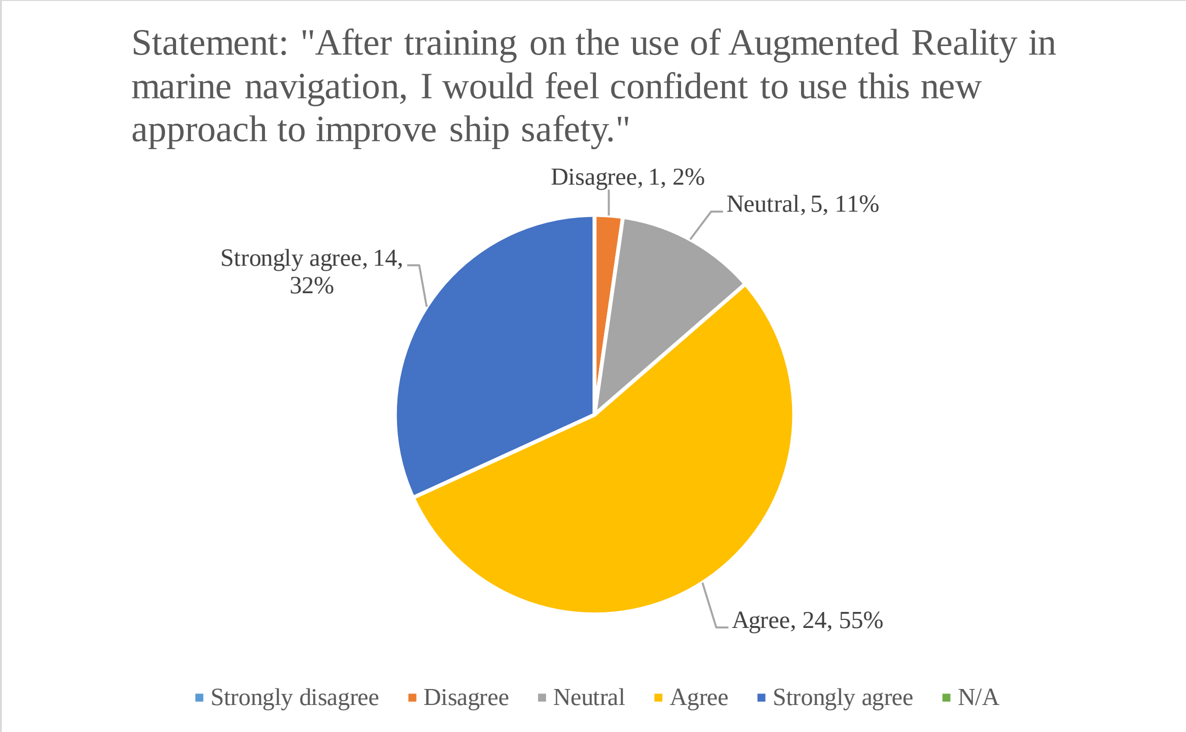
Question 4



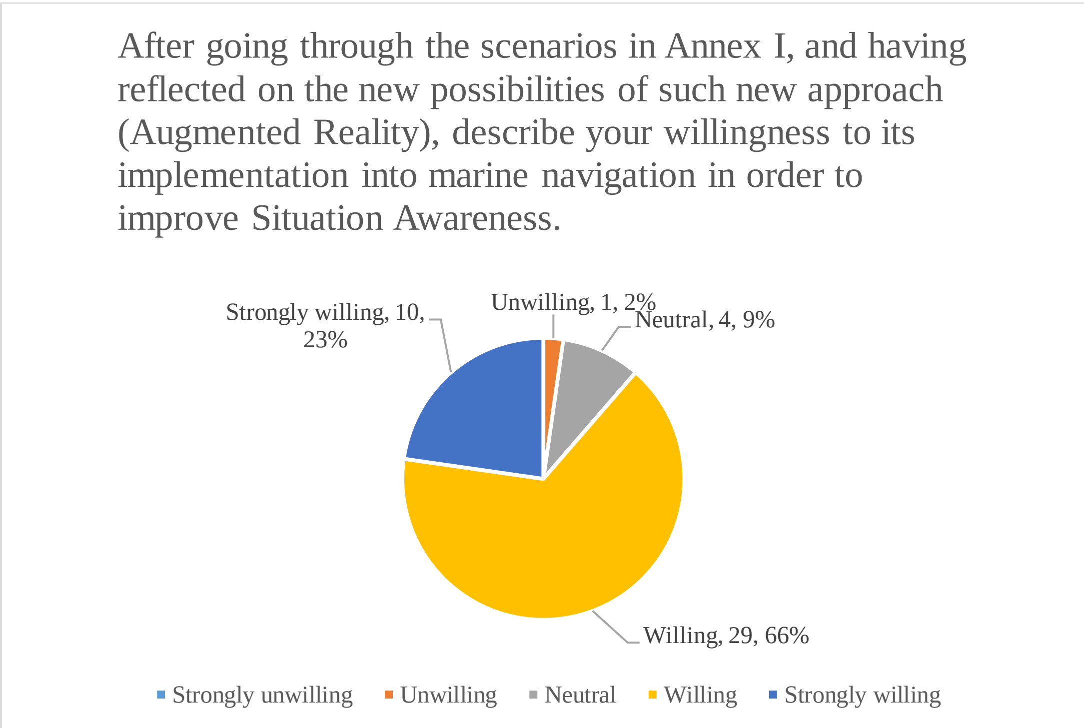
Question 4 (with spread answers)



Question 5



Final question: Question 6



Lastly, what is your age and navigation experience on board merchant or sailing ships?