CHAPTER 6

Whose Mental Model? Multi-stakeholder Most Advanced Yet Acceptable (MAYA) Visions of Disruptive Autonomous Maritime Technology

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Introduction

> We're looking for something that's disruptive but not unprecedented.
> (Gary Hamel)

On March 23rd 2021, the *Ever Given*, a massive cargo ship the length of the Empire State Building became stuck in the Suez Canal, preventing traffic by other ships through the canal (Gambrell, 2021; Stubley, 2021). While luckily no human being was injured, the incident caused great costs in global trade and logistics due to the inability of other vessels to pass through the waterways. The canal was blocked until March 29th, causing an estimated USD$9.6 billion in loss of trade for each day it was stranded

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(Russon, 2021). Reasons for the occurrence were said to be high winds, with the large amount of cargo (containers) acting like a sail. Additionally, it is said that both technical and human error-based errors may also have been at play (BBC, 2021). Nonetheless, on-board the vessel there were 18,000 containers of goods that were seized with the ship over a 900,000-euro compensation dispute, causing additional delays and costs (Paris & Wang, 2021). If nothing more, this incident in the Suez Canal has served to demonstrate the ripple effects of events that occur within contemporary systems. For instance, the effects of goods withheld on the ship can be seen in delays and changes to product schedules and releases in stores such as Aldi (Doody, 2021). Moreover, substantial quantities of fuel (oil and natural gas) for instance were prevented from movement, due to the event. Interestingly, commercial pressure in itself has been identified as a risk factor for safety culture in maritime traffic (Darbra et al., 2007).

In a study of the most influential human factors contributing to maritime accidents between 2011 and 2016, Coraddu and associates (2020) observed that lack of knowledge, lack of skills, ignoring training, safety awareness and cutting corners were major reasons for cargo vessels being grounded or stranded. Devising ways to reduce risk through minimising human error is one main motivation for the drive in autonomous maritime development (Veitch & Alsos, 2022).

With approximately 90% of global trade occurring via sea, the maritime industry is one of the most complex and oldest industries in the world (Main & Chambers, 2015). People remain at the heart of the industry despite the myriad of technologies that are utilised to enable the logistics and traffic flow of insurmountable amounts of cargo and other phenomena (e.g., naval, research vessels, etc.). Sea trade and technology have played significant cultural roles throughout human history. Thus, it should be remembered that humans and their sensory perception exist in many dimensions of maritime vehicles and their movement. Humans are responsible for their conceptualisation (the ideas behind the technologies and how they will be realised), design (embodiment of these ideas through formalisation processes), engineering (calculation and actualisation of design and material properties), operation, utilisation, direction and further significance. Furthermore, in an ever increasingly autonomous maritime environment, humans are increasingly responsible for the programmed logic of the systems (Ahvenjärvi, 2016). Not only do people's ideals, beliefs and values come into play within the development of maritime technology, but so too do the biases, errors and fixations

that are translated from human thought to actionable artefact, service and system.

The chapter applies the Most Advanced Yet Acceptable (MAYA) (Hekkert et al., 2003; Loewy, 1951) principle to understand the current direction and vision of autonomous maritime technology, and then challenge this vision through highlighting its design fixation (Person et al., 2008) –adherence to known imaginings and logic that have accrued through discourse and experience. The theoretical article explains the links between cognition, domain expertise and design to show that through learned knowledge various parties hold differing sets of expectations for desired design features and technological logic. Yet, within the public imagination—and subsequently prevailing technological developments—specific ideas, notably manifested through popular culture and the like, set the path for how future design developments unfold. The aim is to problematise *whose visions* are driving current developments. The chapter is an endeavour to expand future autonomous technology design directions by first highlighting the fixated nature of current visions, and then second illustrating how through re-thinking the human at the centre of the design we may enable a richer Co-human (human-artificial intelligence co-existence) that is not only efficient, but sustainable and humane.

The chapter begins with a brief history on ship piloting, in order to show how it has developed, in light of needs and knowledge. The chapter progresses by discussing human maritime factors in respect to the need for technological innovation, i.e., to increase safety and wellbeing of staff and other stakeholders, as well as to avoid potential disasters caused by incidents such as the Ever Green incident. The MAYA principle is explained, and is followed by a discussion on design fixation and how design fixation guides experiences of MAYA—defining how people recognise the qualities of design and innovation. The mental models of multiple stakeholders are considered in relation to MAYA, drawing attention to the differences of stakeholder groups. The chapter concludes by proposing a model to dismantle the 'one-logic' MAYA—Yet Unknown but Better (YUBB). The overall aim of this chapter is to take stock of the current un-human fixation there is with future maritime design and introduce a humane approach to re-plant the human in the future of the sea.

Piloting and the Human Factor in Autonomous Maritime

As a historical industry, maritime navigation and design have taken many forms and standards. Regardless of the changes in shape, speed, energy, emissions, etc., the general idea of the logistics remains the same—the construction of purpose-made sea-bound vessels that are capable of performing the tasks in question whether it be transportation of cargo, people, fishing or otherwise. The maritime has played a key cultural role throughout human history as it allowed not only travel, but the interchange between products, languages and behaviour that have set forth to shape the multisensory experience and stories of the contemporary world (Paine, 2014). The guidance of seacraft and its crew have differed through the centuries. 'Pilots' or 'guides' of ships were named as early as the sixth century and an even earlier ancestor of the pilot can be seen in literature dating back to the first century AD (FFPM, 2023). A pilot role is an individual who has extensive knowledge and experience of specific waters and terrains in which a vessel is moving, and who serves as a guide to aid its safe passage. Traditionally, due to the vast range of ship travel, captains have not possessed sufficient knowledge of the diverse waters in which they travel. Local pilots are more adept at guiding vessels through shallow and narrow passages. Pilots in this sense, can be understood as the land-sea interface of maritime navigation (Main & Chambers, 2015).

During the 1600s, Dutch pilots became a part of either the ship's crew or piloting organisations. These individuals began to systematically record the surroundings and create sea charts in order to provide guidance and documentation for others. Around the same time, Piloting Acts or national laws regulating piloting began to emerge in Europe. This gave rise to the professional status of pilots. To this day, piloting remains a prominent profession in the maritime industry and can be understood as the key human factor that connects maritime technology (vessels and other navigational equipment) and the elements with human-centred goals (Hontvedt, 2015). While pilots are the key factor in ensuring safe navigation in difficult, narrow and shallow waters, one must not forget the importance of safety for these humans. Due to the challenging conditions including varied weather conditions, long and uncomfortable work shifts, safety concerns for the pilots themselves have often been raised (Darbra et al., 2007).

Psychological and health-related research have focused on the detrimental effects of piloting on body and psyche (Chambers & Main, 2015; Tait et al., 2021). These effects include stress, hypertension and other ill-effects on physical fitness caused by factors such as inadequate exercise levels, stress eating (mental compensatory behaviour) and other unhealthy lifestyle choices (Barbarewicz et al., 2019). Yet, knowing how to address all of these issues—from vessel (s) to professional health and safety—has proved a difficult and debatable task (MacLachlan et al., 2012). One of the most obvious long-term design solutions and moves towards solving these problems has been the idea that if we remove the human element (human factor) from the piloting situation itself with the aid of artificial intelligence (AI), we will be able to remove the likelihood of human factor related accidents (see e.g., Allianz, 2015; Rolls-Royce, 2016). This idea has been in existence for a significant amount of time, and increasingly societal technological efforts have been focused on achieving this goal (Relling et al., 2018). An autonomised maritime is understood as providing the opportunity to adapt to future challenges that include both the need to meet safety and environmental standards, as well as reduce costs (Ahvenjärvi, 2016).

Future Maritime Discourse

In maritime technological discourse there are two prevailing directions through which we understand the future of shipping and piloting: (1) self-navigating vessels; and (2) remotely operated vessels (Relling et al., 2018). Within both scenarios the main aim is to reduce the presence of humans—either on the bridge or the vessel entirely. Changes in the presence of human operators will cause significant alterations in maritime traffic and logic in general. Relling et al. (2018) argue that the removal of humans from the picture of shipping is simply a reductionist idea. Through addressing safety via the removal of human factors, scientists and technologists are simplifying or trivialising complexity. While simplicity in itself can be argued as complex (Rousi & Silvennoinen, 2018), Rasmussen (1997) claims that 'all work situations leave many degrees of freedom to the actors for choice of means and time for action' (p. 187).

The human role within systems comprises an overwhelming number of dynamic dimensions that are near impossible to account for through mere implementation of AI technology. One simple example of this can be seen in self-service checkouts that demand attendance by at least one to four

human staff members—shop assistants and security—for the purposes of usability assistance, alcohol purchase, discounts and theft prevention to name some. Similar to this self-service example, Relling et al. (2018) stress that the emergence of new technological systems also brings new properties and problems that did not exist earlier (i.e., bugs in the automatic piloting programme and vulnerability to cyber security issues). While safety is claimed to be an antecedent for replacing humans on ships, different forms of safety concerns also arise in interaction with the novel components (Levenson, 2004).

While vast investments are currently made into the digital transformation of global transport with the direction of AI systems still being determined, there should be active discussion and consideration for what (ethical and 'best'—efficient, effective, fruitful) direction our techno-cultural society should take. So-called visions of the future are based on established ideas that are perhaps already now outdated. Ahvenjärvi (2016) cites initiatives that began in the 1970s to establish a fully automatic offshore industry that was subsequently demonstrated by Japanese technologists in the 1980s. Fully autonomous un(hu)manned surface vessels already exist in abundance in fields such as the military, coast guards and ocean research.

Complexity of Human-Technology Relationships

There is a symbiosis that exceeds the mere ability for humans to work with technology. Rather, humans should be understood as an intricate part of the systems from logic to outlook and action. The very existence of any type of technology has been defined and created by cultural forces that render the significance of the artefacts and their function (Murphie & Potts, 2003). Technology is formed through human cognition, is an expression of human cognition, and in turn, influences human cognition (Shaffer & Clinton, 2006). With knowledge of humans, human systems and in particular, embodied cognitive-affective processes that have seemingly advanced over the last three hundred years, it would not make sense to revise our traditional views on the future and autonomy of machinery (Rousi, 2020).

Thus, already within the small scope of this current discussion there are two main questions that should be highlighted: (1) if humans are the main point of concern within the safe and efficient operation of technology, why do we need to embed the qualities of humans within

its logic?; and (2) if, from what research has revealed over the last few centuries, humans are still a highly advanced psycho-physiological species in terms of their capabilities for flexible thought, problem-solving, creativity and embodied cognition (unconscious, subconscious and conscious representationalism and processing), then why are they not incorporated more—for what they are—into the design and development of emerging systems? From the outset, humans, human error and human bias cannot be separated from the logic of AI, as AI and all technology are the products of human thought (Ahvenjärvi, 2017; Belk, 2021; Relling et al., 2018; Vakkuri & Abrahamsson, 2018). Yet, failing to acknowledge this and neglect the incorporation of human strengths within the development of a new vision of maritime could prove disastrous from a number of perspectives. None the least, humans *should* be able to live in harmony with autonomous systems.

Addressing Human Factors in Autonomous Maritime Technology

It is reported that anywhere from 50–90% of maritime accidents contributing to injury or death have been caused by human error (Cockroft, 1984). From the perspective of piloting, around 90% of these incidents have occurred in confined waters. Maritime safety, health and well-being can be discussed from a number of perspectives—personal, environmental, community, economic, etc. Much of the literature focusing on the occupation of maritime piloting concerns studies relating to health factors (Main & Chambers, 2015), decision-making and safety (Hetherington et al., 2006), knowledge transfer (Tuncel et al., 2022), communication and leadership (Chauvin et al., 2013; Kim et al., 2021), mental models (Orlandi et al., 2015; Imset, M., & Øvergård, 2017) and personality (Barca, 2019). In particular, problems have been identified relating to stress, fatigue and implications on physical fitness as well as eating habits (Carotenuto et al., 2012; Main & Chambers, 2015). Some of the factors contributing to these pilot-related physiological issues can be seen in the work conditions of the pilots. These conditions can often be characterised as isolated (Darbra et al., 2005) and unfamiliar, waterways and weather conditions can be challenging (Nielsen et al., 2013), and shifts overall are often long and tiring (Main & Chambers, 2015). These are some of the factors that contribute to stress and fatigue. Other mediating factors relate to limited exercise and extended periods of attention and concentration (Cook & Shipley, 1980).

Another contributor that has been somewhat discussed pertains to the maritime pilots as people—personality traits and accessibility for studying. Personality traits can be defined as characteristics or qualities that exhibit people's outlooks, attitudes, motivations and actions (Eysenck, 1976). Often researchers have difficulties in accessing pilots to study. This may be due to a number of reasons including availability (between work shifts), as well as personality traits—both within the individual and their demeanour and/or disposition towards the research, and/or due to the psycho-physiological effects of the work itself. These effects can be described in terms of for instance burnout and over-commitment leading to social disengagement (Basinska & Gruszcynska, 2020; Lehr et al., 2010; O'Brien et al., 2004). Thus, Barbarewicz and associates (2019) highlight that there are possibilities that existing research represents biases within their results, with a tendency to focus on 'healthy workers'—those capable of and willing to engage in studies—while down-playing or underestimating the levels of strain and stress that the maritime pilot population actually experiences overall.

The basic personality traits that are considerably desirable for the profession of maritime piloting can be seen to embody resilience and humility, goal orientation, the ability to cope with change and uncertainty, ability to take control, yet also possess high levels of empathy and intersubjective awareness. These qualities are coupled by the need to be attuned to the environment through the body and its senses, as well as to act and react in logical ways to various situations. These qualities resemble the ideal thinking-feeling autonomous system, or Emotion AI (Zhao et al., 2022). The authors of this article hold the concern that justifications for the design, development and technological road-mapping of maritime technological autonomy to date, have simply focused on the shortcomings of the human factor in maritime logistics (Porathe et al., 2018). This grossly underestimates not only the strengths and sophistication that humans as intelligent organisms in maritime traffic have for its smooth running, but also underplays the valuable role they hold for further technological development in the industry (Ahvenjärvi, 2016). Strong mental and embodied models, combined with personality traits, form a substantial organic (cognitive-affective) database from which technology developers should endeavour to mine and utilise within their design of a human-technology future.

A burning issue in the direction of future maritime technology hinges upon mental (cognitive) fixations. People from diverse fields and professional domains possess fixations, and in the case of the present article, design (idea) fixations of what the future technology should look and be like. The question is—something that is also applicable for the autonomous car industry: Whose fixation are we developing with? Are the intricacies of domain-specific maritime piloting knowledge (mental models and embodied know-how) being taken enough into consideration within the development of future, scalable autonomous technological design directions? And, could in fact, the professional maritime piloting knowledge and *body* be used to dismantle current ideas and deliver even better, unknown (unprecedented) solutions?

Here, we focus on the human role of the maritime pilot, yet in doing so, we offer a glimpse at both the complexity of the human-systems relations, as well as the ways in which we can reconfigure and redefine the parameters of the directions in which emerging maritime technologies should take shape. Psycho-physiological factors influence the ways in which maritime professionals imagine and envision the future of maritime technology and its logic. These human factor-related details affect the 'fixated' image and understandings of what maritime technology is, what it could be and what it should be. The knowledge held by maritime pilots also influences the mental models of what is *Most Advanced Yet Acceptable* (MAYA) within the visions and realisation of future maritime technology. Domain-specific knowledge held by these professionals affects what they understand as being feasible and desirable. Psycho-physiological as well as sociological factors known by maritime pilots also aid in the understanding of how the eventual technological solutions will be accepted and integrated from a multi-stakeholder and multidimensional perspective.

Design Fixation and the Challenge of Making New

Design is an apt arena for studying problem-solving as design problems are often ill-defined (Purcell & Gero, 1998). Ethical design and development (e.g., Saariluoma & Rousi, 2020; Vakkuri et al., 2020) for instance, not only face challenges in ethics and their ambiguity, but in relation to obstacles of unpredictability when conceptualising the future and its conditions. It is important to consider a non-linear and non-fixed way of shaping the future through design—harnessing temporality while abandoning it in approach. Rather than imagining wholes, we should consider

the steady building blocks based on values, principles and consistencies that may be reconfigured in infinite ways depending on what opportunities and challenges emerge. Design problems, wicked, ill-defined or well-defined, always provide opportunities for creative solutions and innovations (Fahey, 2016). Similarly, these domains prove considerably 'wicked' from the perspective of design fixation.

The term 'fixation' is described by the Merriam-Webster (2023) dictionary as the act of fixing or fixating—concentrating and sticking to something. From the cognitive perspective, fixation alludes to the process of blocking the completion of certain types of cognitive processes that pertain to creative idea generation, problem-solving and even memory (Chrysikou & Weisberg, 2005; Crilly & Cardoso, 2017; Jansson & Smith, 1991; Purcell & Gero, 1998). Fixation can be both beneficial and detrimental. On the one hand, fixation can assist in concentration and the strengthening and automatisation of highly practiced activities. On the other hand, fixation may prevent one's ability for flexible and analytical thinking that allows the discovery of diverse avenues (Fig. 6.1).

Design fixation is generated through factors such as attentional blink, whereby human attention is drawn to specific characteristics based on past knowledge, experience and emotional reactions towards particular phenomena (Weingarten et al., 2016). The ways in which humans learn about phenomena and how it is framed (associated with other phenomena

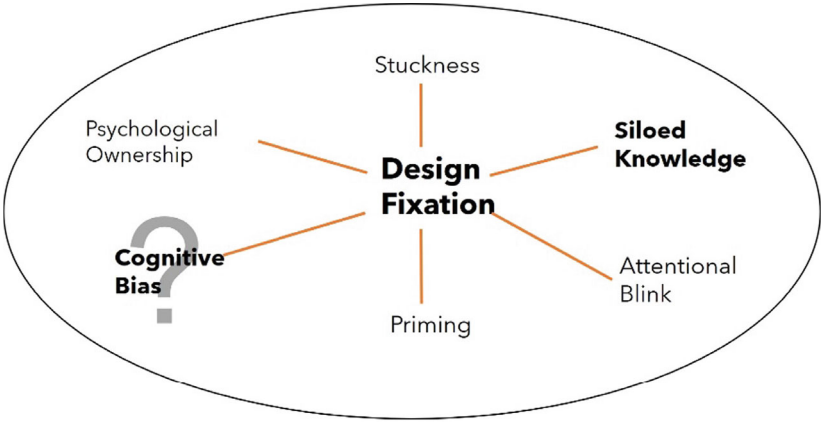

Fig. 6.1 Design fixation (adapted from Crilly & Cardoso, 2017)

and sentiments) shape how phenomena are mentally represented. Design fixation can be seen as a form of 'stuckness' in terms of how individuals understand phenomena (Crilly & Cardoso, 2017).

There is also the element of psychological ownership (PO). PO is the psychological (cognitive and emotional) bond that people have with objects, domains, places, etc. (Asatryan & Oh, 2008; Pierce et al., 2003). This type of cognitive-emotional relationship to phenomena contributes not only to a sense of expertise, or perceived authority over information pertaining to the phenomena, but also determines the commitment one has to matters related to and surrounding it (Pierce et al., 2003). PO is particularly important to remember as this article progresses as it helps explain the relationship between mental models and understandings of MAYA from an emotional perspective.

Across all fields and none the least cultural industries (i.e., art, design, music, etc.) design fixation presents challenges, particularly in terms of creative thinking and bringing designs forward to an innovative and constructive state. Purcell and Gero (1998) have examined this in the context of design sketching especially among less experienced practitioners and students. Arguably in the sketches of students when skills and ideas are still underdeveloped, design students often demonstrate a premature commitment to a solution. Rather than exploring ideas and alternative solutions through research, they often choose from known options. This is also a common problem among more experienced design professionals.

Jansson and Smith (1991) challenged mainstream design discourse by illustrating that despite the designer role of shaping the world and driving novel innovation, designers are fixated with particular ideas. Through exposing designers to images of possible design problem solutions before a design session, designers become fixated with details of the images and their overall conceptual properties. Exposure to prior ideas and conceptualisations dramatically affects the means through which designers envisage the potential design outcome. Prior exposure blocks mental access to alternative ways of solving design problems. Purcell and Gero (1998), argued that the foundations of fixation originate from the necessity to draw upon two types of mental representation of the problem itself: (1) the *conceptual space*—abstract knowledge of principles, rules and concepts that may be used as tools for problem-solving; and (2) *object space*—physical objects, elements and features that may be appropriated within the concrete design to practically solve the problem. Difficulties rest in the

ability to shift from the object space to the conceptual space—that is, from looking directly at known and materialised solutions to problems towards looking at the problems and their properties in themselves, in order to discover different pathways towards the solution.

There is also a very practical cognitive explanation for the preference of object space and drawing on previously known physicalities in our problem-solving processes. This explanation rests on cognitive-affective preferences for the familiar (Monroe, 1976; Rousi & Silvennoinen, 2018). Familiarity increases processability, as repeated exposure means increased opportunities to learn the presented information, its patterns and sequences. This in turn becomes cognitively embedded, increasing processing fluency (Reber et al., 2004; Zajonc, 2001). Thus, it is little surprising that designers either consciously or subconsciously gravitate towards known solutions as this form of preference is hardwired into human cognitive-affective processing. The necessity to revert to the *conceptual space* when analysing ill-defined, wicked or perhaps any design problem regarding true innovation, demands greater levels of higher-order cognitive processing (abstract and critical thinking) (Weiss, 2003). Or, in other words, higher amounts of cognitive load.

This provides a clear hindrance in the fostering of future design directions as both designer education, and industry, rely heavily on already existing examples and visioning. Images and scenarios that are significantly old often take hold in the design ideation and processes for emerging technologies as they have become cognitively incubated through culture (Edwards, 2010). The impact of this is pronounced because the same models that are used to train or familiarise designers with particular ideas and approaches are also the ones that form the basis of the understanding within designers' minds of what the solution will be like. The role of the professional domain in shaping individuals' mental representations of phenomena, problems and their solutions is subsequently of interest for the purposes of this current article.

Conceptual Design and Disrupting Fixation

Conceptual design is a process in which ideas (concepts) are generated, deliberated, analysed, evaluated and selected generally at the beginning of a design or development process (French et al., 1985). This is considered to be a front-end process that is implemented shortly after identification of the need or problem in question (Jansson & Smith, 1991). The aim of

this design phase is to set the foundation for the main technical concept of the project. While on an overall scale, the time spent in this phase is relatively short, the effects of this phase may carry major implications for the subsequent phases, direction and outcome of the process. In other words, the early conceptual development provides a critical step in any design project as it foregrounds the vision, steps and framing of not simply the output of the process but also of the conceptual contents of the design problem.

Within this phase, Jansson and Smith (1991) outlined that once again, designers and developers are engaged within two mental or cognitive spaces: (1) *the conceptual space*; and (2) *the configuration space*. While we have already briefly described the conceptual space and its function in dissecting, rearranging and analysing design problems in relation to their conceptual building blocks, the configuration space is the space in which designers actively construct alternative solutions for these problems. The configuration space is different to the physical space in that the physical space is a zone in which physical stimuli, and memories of physical stimuli inform the conceptualisation of the problem's solution. Yet, the configuration space can be seen as an area of opportunity in which the basic elements generated within the conceptual space may be configured to create something new.

Thus, the configuration space can be understood as a productive imaginary space in which information is arranged into operational solutions. This is the area in which the potential (precedented and unprecedented) physical object is mentally represented. These solutions include anything from rough sketches and names, to storyboards, narratives and the actual overall product or system itself. In order to deliberate and develop functional ideas within the configuration space, as usually happens within any design and development process, there is interaction between the configuration and conceptual spaces. The conceptual space in which understanding of the problem at hand occurs, often influences and causes changes within the configuration space. Alterations to the configuration space are motivated by changes in the levels of abstracts and mental representation of concepts. Changes can only occur within the configuration space through alterations emerging in the conceptual space (see Fig. 6.2).

There is the need to understand how to encourage design problem-solving deliberation processes towards the conceptual space rather than directly to the object space. Additionally, ease of movement and flow between the conceptual and configuration spaces should be made fluent.

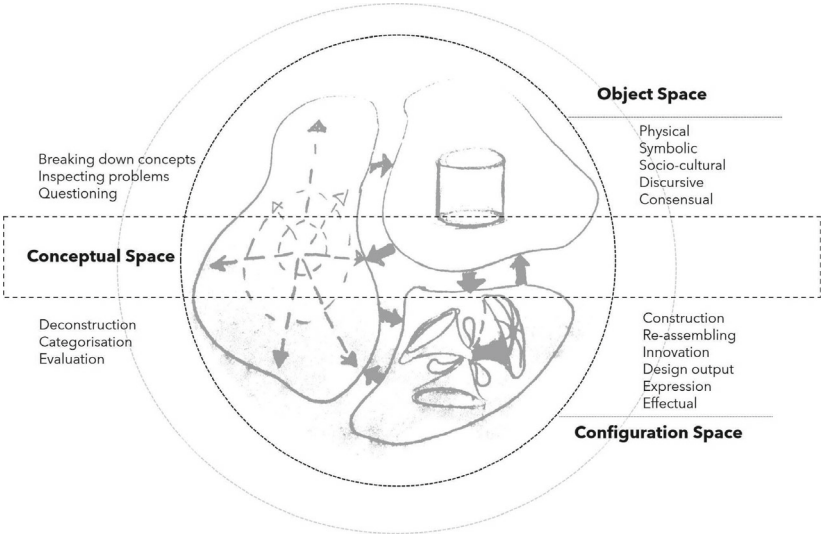

Fig. 6.2 Design spaces model

Obstacles that prevent the ability to understand design problems in an abstract manner, and then configure these understandings into operable compositions, then back again, should be identified and addressed. *Discovery* in the conceptual design sense means a journey in which designers identify as many alternatives and opportunities as possible, not simply for producing a solution but for uncovering the multiple facets of the problem. Design is a research process.

Through this conceptual model it is understood that there are several ways to tackle fixation and encourage movement between the mental spaces. One method to achieve this is called the Parameter Analysis (PA) in which designers and developers identify and explicate the boundaries of spaces relevant for various domains of knowledge (Jansson & Smith, 1991; Moreno et al., 2015). Not only does PA identify and separate the conceptual space into domain-specific spaces, but the identification of the relationship between the object space and the conceptual space is held vital. Unfortunately, design fixation involves a form of conceptual and configurative blindness that may confound problems rather than

solve them.[1] Design fixation manifests in repetition, similarities, being 'stuck-in-a-rut' and non-explainability in designer-led decision-making.

Implicit commitment to one strain of thought is often referred to as 'mechanised thought'. This is a cognitive process that follows a previously established method of thought. Mechanised thought, or functional fixedness, is a type of long-term cognitive block that is contextually bound and situationally induced (Luchins & Luchins, 1959). When thinking of the technological future there are usually biases towards understandings of machines that will eventually function autonomously. Seeing beyond autonomy is perhaps the most challenging, yet pertinent objective that may be placed, particularly when considering the development of an ethical human technological future. Rather than turning towards previously established examples of what the future will look like, perhaps a more profound way of addressing the future through the design would be to re-focus towards the conceptual building blocks of the design problems in question (Jansson & Smith, 1991).

Most Advanced Yet Acceptable

The design fixation section focused on characterising the ways in which designers become fixed, or stuck, with previously represented ideas. Related to design fixation is the notion of Most Advanced Yet Acceptable (MAYA). MAYA was coined by futuristic designer Robert Loewy (1893–1986) to describe the way that designers should aspire to negotiate between the known and the new in order to generate designs that were both seemingly novel, yet palatable by larger groups of people (Friis Dam, 2021). The idea behind this relates to the ways people seek novelty and a sense of progression within the products they consume, particularly in light of evolving cultural and societal trends, or fashions (see e.g.,

[1] Consider the potential problems of dismissing humans in the development of future autonomous maritime technology—unemployment, bias and severe consequences for human safety—when all the conceptual components are not incorporated and adjusted within the configuration space. Simply stating potential, for instance, ethical implications is not enough when the execution of a design concept that precedes ethical deliberation in the conceptual space is undertaken. This will result in a double-layer (compounded) ethical dilemma within the system: (1) that the ethical considerations were not actively accommodated for within the design and development process; and (2) that it is known that ethical deliberations in the configuration space should be made during the early stages of design and development engagement.

Rousi & Alanen, 2021; Saariluoma et al., 2021), yet they prefer elements of familiarity in the designs and concepts that are emerging (Hekkert & Leder, 2008; Thurgood et al., 2014). The human mind prefers familiarity as it enables efficiency and fluency when identifying and processing information in the form of patterns (Rousi & Silvennoinen, 2018). This also enhances reactivity in relation to social-emotional cues within the designs (Rousi & Alanen, 2021).

Loewy was well known for his designs of the US postal service logo, Coca-Cola bottle, the Shell Oil logo, Greyhound bus logo, Airforce One logo and others. The challenge that Loewy identified was that although there may have been vast alternatives available for solving design problems, the adult mind draws heavily on known representational (physical or other symbolic) examples in order to identify and accept phenomena for their function and purpose. This is often referred to as typicality (Thurgood et al., 2014). Typicality increases the likelihood that mental information contents match the encountered design (Saariluoma & Rousi, 2015). As Loewy (cited in Friis Dam, 2021) argued,

> The adult public's taste is not necessarily ready to accept the logical solutions to their requirements if the solution implies too vast a departure from what they have been conditioned into accepting as the norm.

Like computers, humans are programmed—socially and culturally conditioned—to perceive, recognise, process and respond to phenomena through discrete laws of logic (Hofstede et al., 2005). Children may be seen as more open to new ideas and alternative ways of understanding phenomena, as their mental representations of how things 'should be' are not as fixed (fixated) as adults (Vygotsky, 1980). What children as socially learning (Bandura & McClelland, 1977) beings do, however, is looking towards their role models for ideas and standardisations on beliefs, behaviour and practices. This means that they learn and are conditioned into particular ways of processing information, and associate specific meanings and codes of behaviour accordingly. A solution may be preferred because it resonates physically, symbolically or behaviourally with what is already known through previous exposure (i.e., through cultural and social discourse). Yet, the contents of these cognitively established solutions that exist in the object space may not properly match or address the contents of the problem existing in the conceptual space.

Viewing future maritime technology through the lens of MAYA, it may be questioned as to whether the removal of humans from the sea vessels will eliminate incidents involving human error. Or, whether there is an entire field of issues implicated in this removal that indicates the necessity for designers and developers to re-enter the conceptual problem space of maritime design. Already at this point, issues have been raised concerning the potential exacerbation of human error through AI programming and lack of maritime expertise among developers (Ahvenjärvi, 2016). Moreover, other identified ethical problems such as the displacement of human workers, complexity of responsibility and accountability, ambiguity of logic and blurring of transparency, may be caused to not simply remove humans from maritime technological systems, but instead, revise their roles within these systems.

At this pivotal point in technological history, the point at which AI, remote, autonomous and embodied systems are becoming infiltrated in societies, the role of the human needs to be revised. There is an urgency to understand how technology and its ecosystems can best serve human and humane purposes, and can be best re-configured to address the burning issues that have inspired the now-fixated ideas. These issues include safety, accuracy, speed, efficiency, quality and sustainability (environmental, social, economic). In order to do this, there is the need to better understand how and whose ideas the design fixation has been formed upon. The following sections focus on questioning prevailing design visions on autonomous maritime technology development through examining the mental models and issues concerning maritime pilots in particular. This information is then compared to the mental models of various actors from diverse domains including designers, developers, policymakers and general public. The details affecting the ways in which maritime pilots form their mental models of the industry and its technology in addition to professional knowledge, include the professions impact on skills and embodied knowledge, responsibility, stress and physical factors.

Revising the Removal of Humans—A Quick Check

When analysing the nature of autonomous technology, we may refer to Leveson (2004) who highlighted that by establishing independence from a human operator through installing or building an automatic, or autonomous device, the risk for human error simply shifts from one

player to the next. The responsibility effectively moves from the heavy machinery operator to the designers and development team. If errors are inherent within the system they devise, the result will be not simply that one vessel misbehaves, but all vessels. Particular errors would be repeated throughout the entire 'autonomous' system, which may at worst be catastrophic. When reviewing the above-mentioned causes for major maritime accidents, it should be noted that two of the primary types of faults rest in *leadership* and *supervision* as well as *organisation*. Perhaps more attention should be placed on how to utilise AI to support leadership and supervision, and even to advise on the organisation of operations—from business and society to workload.

In order to develop a more effective, safe, ethical and sustainable maritime, we should be focusing on human strengths within the industry. Afterall, logistics, sea transport and portside processes are human. They have been developed by humans for humans. As designers and builders of the sea vessels, humans provide the best interface between the ships, the natural elements, artificial elements and human systems, provided that they have enough skill, experience and the right personality traits to negotiate these high-pressure activities. Moreover, it is the minds and bodies of pilots who have interfaced sea vessels and the elements for thousands of years. These should be the informants of future maritime technology development.

One challenge for developing a highly automated, remote or autonomous maritime, is the transferral of knowledge from human experts to artefacts and systems. The reason being, is that we may consider human knowledge as an iceberg. The amount of knowledge that people can consciously explicate, or voice aloud, is a portion of what they actually know (Fig. 6.3).

As Fig. 6.3 illustrates, a significant amount of expert knowledge is implicit (Baars, 2011; Collins, 2010). One of the fundamental problems in technology development is the transfer of the *best human-based information* (data)—expert domain knowledge—into system logic. The greatest challenge with this task is posed by the quantity of tacit knowledge that is relied on in day-to-day activities. Everyday operational knowledge, with its embodied, qualitative (experiential), sensual (semi- and unconscious sensations) and automatised (expertise beyond the point of representation—disappearing 'self-talk' and engagement in the flow of the tasks through action) (see e.g., MacIntyre et al., 2014; Montero, 2016) nature is difficult if not impossible to linguistically represent.

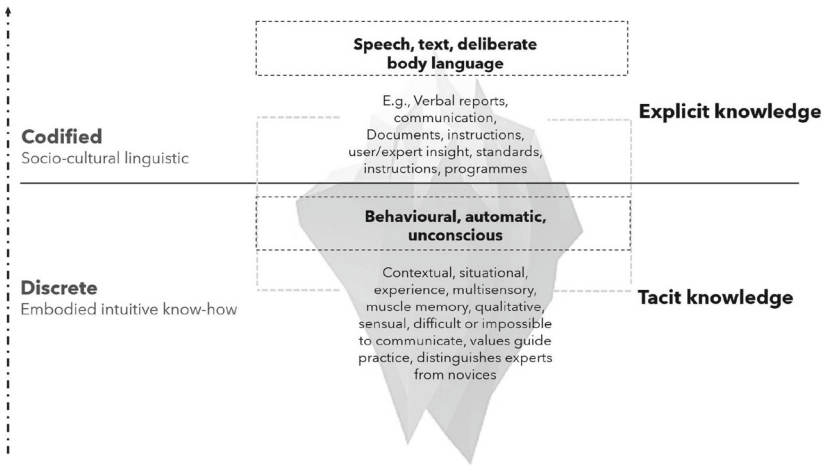

Fig. 6.3 Knowledge iceberg—Explicit versus tacit knowledge

Mental Models of Maritime Pilots

The transferral of human professional maritime knowledge and logic, is to date, impossible in its entirety. Interviews, conversations and observations are limited in efforts to develop maritime systems that can compensate or even improve the performance of human pilots and crew. The major findings of De Maya et al.'s (2020) study on human-based contributions to maritime accidents were: (1) improper design, installation and working environment; (2) inadequate leadership and supervision (similar to Coraddu and colleagues (2020)); (3) inadequate safety management system—inadequate procedures or deviation from Standard Operating Procedure (SOP); (4) inadequate safety management system: substandard monitoring; (5) lack of communication and coordination; (6) lack of safety culture; (7) lack of training; (8) lack of, improper or late maintenance; and (9) unprofessional behaviour. In fact, Batalden and Sydnes (2014) also found that unsafe supervision was the main contributor to extremely serious maritime accidents in 34.7% of cases analysed in their study, while it contributed to 23.1% of serious accidents.

This type of information shifts the dynamics from an understanding of humans *in general* affecting the safety of maritime transport, to specific humans, roles and actions that have been discovered time and time again

to contribute to maritime accidents. In this light, focus should be placed on elements pertaining to leadership and supervision, safety systems and culture (including attention to maintenance and the condition, as well as age of equipment, and leadership in the 'higher' executive sense that decides over resources and culture development). This entails that the ideal cognitive approach to the conceptual deliberation of future maritime technology would be an in-depth examination of the mental models, motivations and needs of top-level executives, managers and organisational designers. In other words, it is often the people determining the technology, systems, procedures and protocol that contribute more significantly to incident on the seas, than those who are on the vessels themselves.

With this said, if we move back to a more traditional sense of understanding the development of an autonomous maritime and fairway (navigable waters and channels) from the perspective of pilot cognition, we should observe the mental models of these professionals. Mental models can be described as cognitive frameworks that are generated by people to interpret phenomena in terms of purpose, form, response and other semantic contents. Mental models provide individuals with 'explanations of system functioning and observed system states, and predictions of future states' (Rouse & Morris, 1986, p. 7). Rouse and Morris (1986) also emphasise that human mental models are not necessarily computational models. Within a design context, and particularly that of future maritime design, it is useful to consider mental models as being purpose-based (see Fig. 6.4).

Through adapting Rouse and Morris' (1986) framework we can understand a mental model as one that *describes* the purpose and form, *explains* function and state, and *predicts* state. In turn, the purpose alludes to why a system exists in the first place. *Purpose* is linked to human motivation and is determined by values and basic needs either directly or indirectly (Maslow, 1958; Troland, 1928). The purpose of an autonomous maritime is stated as aiding sustainability (our physiological human need to have a healthy environmental ecosystem) as well as increasing effectiveness (accuracy and precision), safety (physiological need) and efficiency (time and money—meaning that there is greater potential profit for the companies). Autonomous technology is also experienced as a threat to employment (physiological, psychological and self-actualising needs) and even safety (threat to physiological safety through error or even take-over).

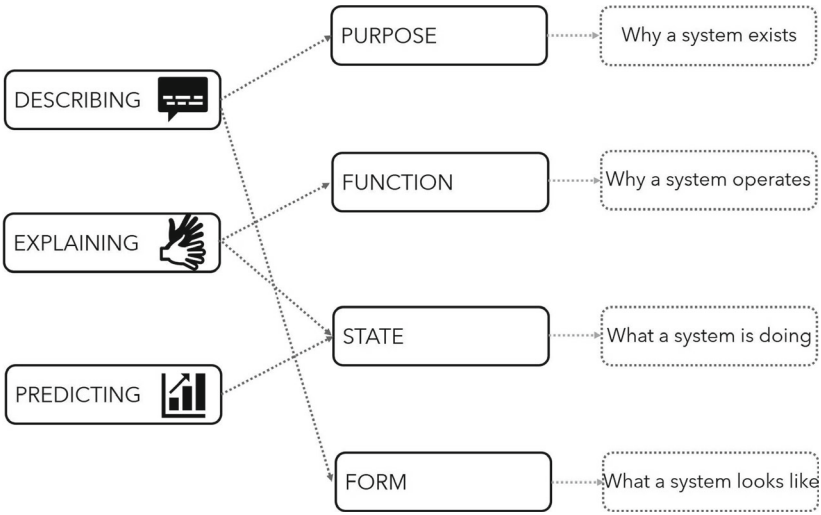

Fig. 6.4 Mental models in design (adapted from Orlandi et al., 2015; Rouse & Morris, 1986)

Some mental models are paramount for the construction and creation of a safe and effective autonomous maritime, these include pilots' abilities to predict and judge (visually, spatially, temporally) the vessel's physical dynamics in relation to manoeuvres (Orlandi et al., 2015). Parts of these mental models are about what can be expressed verbally.[2] This is also known as *perceptual access reasoning* where, through mental representation and association with linguistic and explainable constructs, individuals are about to describe what they are mentally 'seeing' (Fabricius et al., 2021; Lopes, 2000). Yet, a great proportion of knowledge and its structures that are held by domain experts and field professionals pertains to what cannot be mentally represented or verbally expressed, i.e., embodied or bodily knowledge—that which cannot be succinctly represented (Preston, 1994; Smith, 2013) inherent to tacit knowledge. Thus, speed and its management, propulsion type and manoeuvres of varying

[2] This is where we enter the domain of representational theory of the mind (see e.g., Fodor, 1997; Sterelny, 1990).

degrees of difficulty are processed by maritime pilots for instance, through ontologies that cannot be readily verbally expressed.

Mental models describe dynamics between abstract elements and concepts through cognitive processes such as deductive reasoning and inference (Aronson, 1997) or affective processes such as Appraisal and Core Affect (Roseman & Smith, 2001; Scherer, 1999). They are not, however, limited to an individual's mental construction, on the contrary, social interaction and social cognitive processes play a major role in how people gain particular understandings of phenomena (Augoustinos et al., 2014). That is, common understandings and specific ways of seeing systems in domains and through paradigms greatly occur via social actions such as teamwork (Banks & Millward, 2000). Planning and visioning strengthen shared understandings and thus, particular types of mental models in teams (Stout et al., 1999). They are knowledge structures, or ways of formulating and representing information, that occur through relatively stable and repetitive interactions of greatly unchanging representations (Johnson-Laird, 1983).

Conclusion—Yet Unknown But Better (YUBB).

Pertinent to remember is that it is often the people determining the technology, systems, procedures and protocol that contribute more significantly to incidents at the sea, than those on the vessels themselves. John McDermid (2020) highlights that one of the main challenges in bringing autonomous vehicles into mainstream traffic hinges upon the difficulties attaining agreement across sectors and standardisation bodies regarding algorithms, training, testing and validation. There are also problems in developing machine learning that can be deemed as safe. Hubertus Bardt (2017) emphasises the complexity of not only autonomous vehicle implementation but also production, i.e., economics (i.e., Europe and associated regulations) and the implantation of big tech in these vehicles. Again, regarding the design there is a need to understand how various levels of expertise affect mental models. These mental models are built into the logic of the AI and ML systems, while strongly affecting the human dimension and human interaction with the end products. As with the automotive industry, the maritime and its structures are highly complex. To give a simplified example of the mental model challenges faced with envisioning and developing the field of autonomous shipping and piloting, we can focus on four major stakeholder groups:

(1) the pilots and sea crews, (2) shipping engineers; (3) software engineers; and (4) general public—including some members of policymaking communities.

YUBB combines multi-professional knowledge from across stakeholder groups to go beyond MAYA (Rousi et al., 2017). YUBB invites uncertainty and ambiguity through not only combining different perspectives on the design target in question, but different types of knowledge—from the cultural-discursive through to the embodied, affective, and technical. In Fig. 6.5, we observe at least four possible MAYAs: maritime experts (engineers and seafarers), as well as software developers and the general public (policymakers and business specialists included). The cognitive dimensions of MAYA play out through the embodied, cognitive and affective relationship the diverse expert groups have with the topic of autonomous maritime. For the pilot and sea crew, mental models of the future are based on embodiment, dynamics, professional and technical knowledge. For the engineers, future potential is based on technical knowledge of the artefacts, their operation and predicted capacity as well as scientific knowledge. Software developers often possess knowledge dominated by systemic software logic and a form of technical understanding of the machinery and its conditions. The general public represents the sphere of collective imagination in which the maritime comprises cultural ideals, discursive elements (i.e., regarding the transitions in human labour, etc.), social layers (what this means for an individual through to societal livelihood and wellbeing) and the personal world of one's own imaginings.

Ahvenjärvi (2016) questions the ability of designers to anticipate the varied scenarios an autonomous ship could face. Autonomous ship traffic does not equate to un-humanned maritime. While autonomous ships may interact with one another, there is also the factor that not all ships will lack human staff. How then, will an autonomous ship interact with the deck officers on another ship? Perhaps, via ChatGPT or a similar large language model. There is still much potential that should be explored regarding how future maritime technology could be realised, not only in the most efficient way, but maybe the most imaginative. Where effectivity comes with affectivity and a complete transformation of what seafaring is about. Real-time software systems, data structures, algorithms, task priorities and self-diagnostics are just some parts of these complex systems, yet not the all-encompassing cybernetic ensemble of human-technology symbiosis.

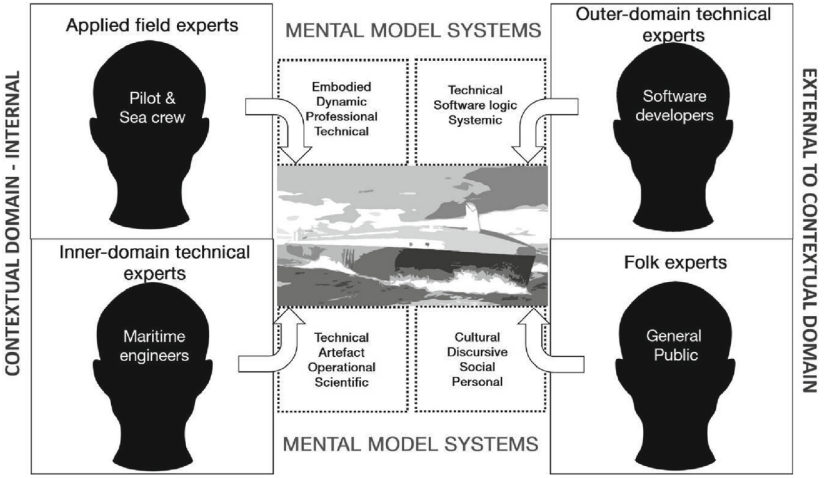

Fig. 6.5 Yet unknown but better—MAYA in multi-professional mental model systems

Rather than holding design hostage with outdated non-humanned models, multi-professional design teams should truly engage in hybrid re-imaginings of the maritime future, in which not only are the accident-prone functions of human being safety-netted through technology, but the strengths of humans are kept in synergy with the intelligent systems. Human operators possess flexibility of thought, tacit knowledge and creativity. The human ability to adapt to surprising situations has positive effects on the safety of the system, although the human ability to adapt - i.e. the ability to learn—may also be a drawback or delay. Software developers have difficulties in predicting the unpredictable outside their own knowledge domain. Human pilots and other sea crew may not have a perfect mental model of the unexpected, but what they do have is a broad set of information nodes, built of previous experience that can be drawn on like a tool kit in times of trouble—storms, fault machinery or even pirates.

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