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Piloting By Heart And By Chart

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This paper describes the complexity of the Baltic archipelago, and the navigational and operational processes involved in piloting these waters. This four year ethnographic study shows how piloting is learned, performed, and passed on to the next generation of pilots. The blend of new technology and old methods is discussed, the indivisibility of working and learning, and the individuality of the mental constructs of the mariners/pilots.

KEY WORDS

1. Archipelago navigation. 2. Marine pilots. 3. Spatial mental models. 4. Lifelong learning.

1. INTRODUCTION. "Piloting, as commonly understood, is a straightforward matter … Actual piloting practices are far more complicated … and are poorly understood, even within the marine community." (National Research Council, 1994, p 67).

In this paper we will describe and unpack marine piloting by reference to charts. Piloting has changed somewhat since charts became available to all mariners. As Putman writes: "… for centuries mariners … composed their maps as they sailed, making unknown waters and territories familiar." (Putman, 1983, p7) Piloting of today is not so different; mariners still compose 'maps' to make waters familiar so as to navigate them. Pilots use external charts and internal charts, and our interest here is how they are linked and how information is transformed in that linking. Successful linking of these external and internal charts is what makes for good piloting and planning. Bowditch describes the practice: "Piloting or pilotage: navigation involving frequent or continuous determination of position … to a high order of accuracy." (Bowditch, 1976, p287) He continues to describe how the ability to always keep "ahead of the vessel", i.e., successful piloting, often means the difference between safety and disaster. Whereas it is one thing to know the 'mechanics' of piloting, the polish and precision of the professional navigator can come only with experience. Given the complexity of these operations and the importance they have onboard, it is surprising that the maritime research literature contains only a few studies of piloting and pilotage (Hutchins, 1990, 1995, 1996; Norros & Hukki, 1998).

This paper describes how the pilots studied commit the chart information to memory and how this information gets used in practice. We will discuss several types

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Table 1. Particulars for Baltic ferries.

	20–30 years ago	Today
Length, metres	100–150	150–200
Breadth, metres	17–25	25–32
Passengers	1000–1500	1500–3000
Speed, knots	16–20	20–23

of charts: sea charts (paper or electronic), personal charts (a mostly mental chart) which are part of a plan-for-action, course books (a paper artefact) and radar charts (pre-programmed lines shown on radar screen). We here break the learning process into three parts, working as a watch officer, constructing the course book, and filling in the blind charts.

2. METHOD AND CONTEXT OF WORK. Over a period of 4 years, we studied 15 ships, of which some are large Baltic ferries, some smaller archipelago vessels and some cargo vessels. Generally across ship types, piloting is about memorising chart information and, with the help of extensive experience, making flexible and dynamic plans for passage. All of the ships studied have Swedish-speaking crews, and the transcripts have been translated by the first author. The data collection method used was mainly observation, and informal interviews with the officers and pilots while driving (on watch), studying or being tested in ship simulators. We also spent time looking at how officers prepare for their theoretical exam. Interviews have also been performed with the pilots and officers off watch, with mariners on leave, and with pilots working for the Swedish Maritime Authority (SMA).

We have studied a selection of the passenger ships in the Baltic sea, journeying back and forth between the Stockholm area and ports in Finland and Åland; a round trip may take half a day, one or two days depending on the route. The ships are combinations of cruise ships, freighters and commuter traffic, and are on tight schedules, just like any bus or train. These ships are fairly large in relation to the archipelagos they pass through, waters which have been described as 'island-studded' and 'tortuous'. Typical measurements for these ferries are shown in Table 1.

The archipelagos of Sweden and Finland are filled with islands and shallow waters, and as can be seen in Table 1, ship size and speed have increased over the years. In this type of archipelago, navigation, or rather piloting, becomes more demanding and complex and in many cases more dependant on technology. As the relative space for ships is shrinking, especially when meeting other ships, manoeuvres have to be performed with margins counted in metres and seconds. As an example, a pilot, N, tells us about a narrow passage: "*You have to be on course, you can't counter the wind by 7 degrees, the … [relative breadth of the ship] increases by 3–4 metres per degree … then you are 28 metres wider when you have to go through … here you have maybe 10–15 metres [clearance] to each side*" (17P-261-264). No longer is it the case, as commonly believed, that ships' crews have so much more time and room to think and plan than for instance aviators.

The standards of safety in these ships are among the highest in the world. The technological equipment of the bridge is what is known as 'integrated navigation (or

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bridge) systems', a workplace with two or more seats where most of the navigation information and controls are accessible to both officers. For reasons of safety and economy, the shipping companies prefer to have their own officers train for a pilot's exemption for the routes the ships travel. This is done rather than for every trip taking on board a pilot who, while a local expert, is not part of the bridge team and is possibly not as familiar with the bridge technology as the crew. To get a pilot's exemption an officer learns the same things as a pilot would do about this passage, and is examined and certified similarly to a local pilot. In this paper these officers will at times be referred to as pilots, even though the formally correct designation is *deck officer with fairway permission* or *deck officer with pilot's exemption*.

3. LEARNING TO BECOME A PILOT. Piloting involves a special kind of navigation and passage planning. When piloting most of the chart (and other) information has to be known by heart, whereas for a navigator it can be enough to compile and browse the information. When this planning is done and the ship is underway, a pilot must refer not only to the memorised chart information but also landmarks, surrounding traffic, both merchant and leisure craft, what the weather is – including visibility (fog, snow), wind direction and force (and how this affects the ship) and ice conditions. Important factors are also the ship-specific details, of size, speed, engine power, steering and turning capabilities and current draft. For successful piloting a mariner has to integrate all of this to form an appropriate plan for action; not only where the ship is going, but also how she is going to get there. For pilots, when the geography is learned it is transformed into a model for use.

For a pilot, when all has been learned (which we will discuss at length later on), it is time to take the pilot examination. This examination, administered by maritime and piloting authorities consists of two parts; a theoretical test and a driving test. Usually the theoretical test has to be taken first. The theoretical examination is also two-fold; for one, the officer fills in "blank charts" for the whole route. In Figure 1 we show one of the 11 sea charts for one of the Stockholm archipelago routes (a blank chart is shown in Figure 5).

The second part of the theoretical test is the examination of the officer's course book. A course book is a personal file with copies of all the charts for the route, which is filled in during the training time (about one year for this particular stretch) with information relevant to the trip and the ship. Both the blank charts and the book should contain essentially the same information: chart information such as names of islands and waters, depths, aids to navigation, characteristics of lights and ship-specific information as specified above. The filled-in charts and the course book are examined by two examiners; two pilots or an SMA employee and a pilot, and discussed with the officer. The examiners can ask the officer to clarify or add points during the examination. But generally, most of the information has to be in the charts and the book. There is not complete agreement on how much the officer should fill in on the blank charts. Most examiners agree that it is not necessary to know everything on the original chart, but candidates must know data relevant for the ship's route. Figure 2 shows an enlarged section of the chart which will be used to exemplify the learning process throughout the paper.

To be eligible for the driving test, the officer must have travelled the route at least 50 times (25 each way); in practice it is usually many times that amount. For the

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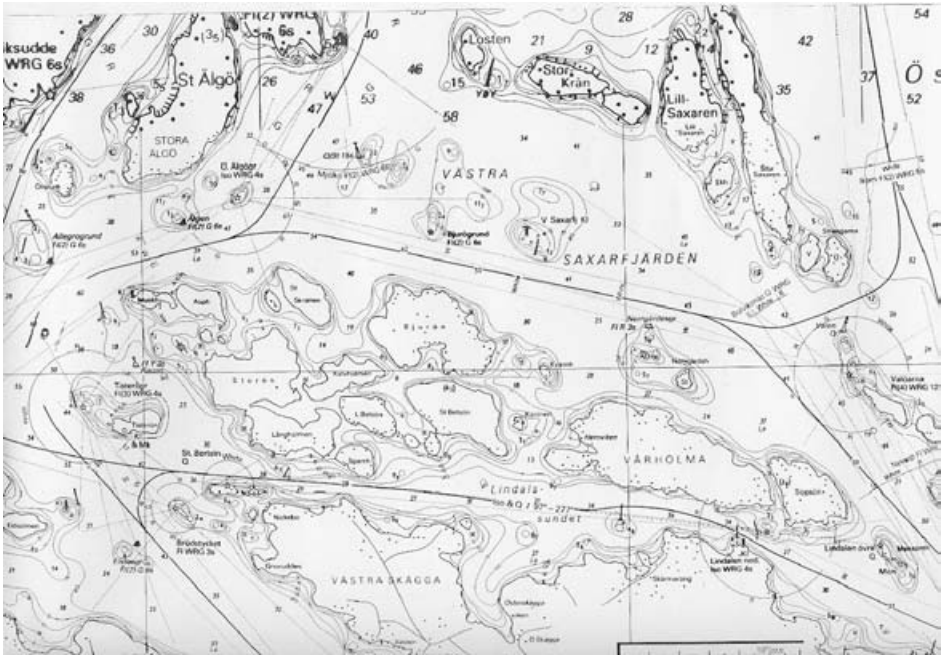


Figure 1. One of 11 sea charts for the Stockholm archipelago.

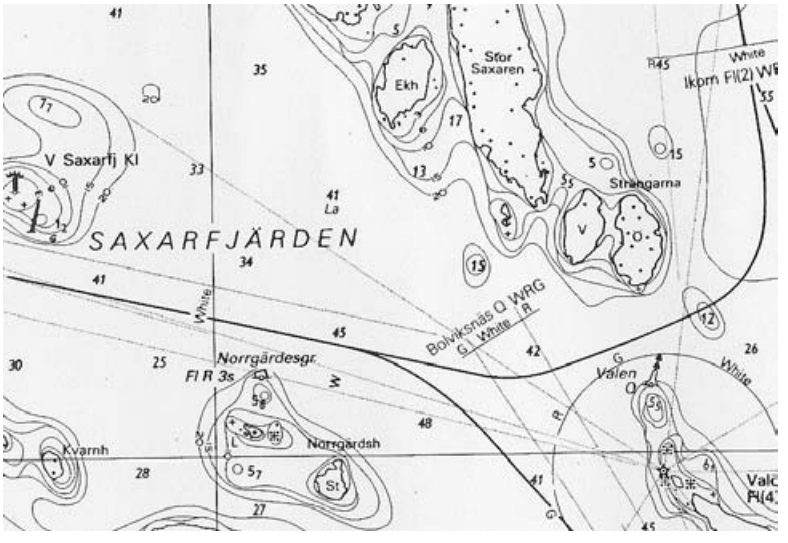


Figure 2. Section of Figure 1.

driving test two professional pilots join the trip and watch the officer navigate and manoeuvre. Here, too, there is some disagreement over how the examination should be conducted. How much use of modern technology should be allowed? Many older and experienced officers and pilots believe that a pilot should be able to pilot the ship

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with few modern navigational aids. The pilot should have, many examiners believe, landmarks (in good visibility) and also be able to navigate solely by radar (in restricted visibility). But the high-technology ships in question here use technology and automation on a daily basis to navigate safely. Should the pilot-to-be show proficiency in the navigation which will be performed every day, or in skills that seldom are used? Some argue, including both active mariners and authorities, that manual skills need to be retained. This is still an open issue.

Historically in most waters pilot and ship's officer are two separate professions. On these ferries, pilots did not always have a high status – in earlier times it was lower than ship's officers. Many decades ago, a pilot did not need as much academic training – local knowledge about the waters was seen as more important. Today this is changing, but this is a transition and takes time. A pilot's exemption is given for a specific route and for a specific ship. The exemption can be valid for two ships but only if they are sister ships, i.e., practically identical.

4. STARTING OUT AS A WATCH OFFICER. The learning process for the three parts, course book, blind charts and driving are intertwined in time and content. We will describe them in turn, and end with a section in which the threads are pulled together.

On the large passenger ferries in the Baltic, two navigators are on watch all of the time in restricted waters (shallow or narrow waters), of which one is a pilot and the other a watch officer. When a new officer joins one of these ships he will start as a watch officer. The watch system is modelled on the 'pilot-co-pilot'-system in aviation. The pilot sits in one designated seat and the officer in another. The tasks are divided between the two, so that the pilot is responsible for driving the ship and the watch officer takes care of "the bridge" as they say: reporting points, radio and telephone communications (internal and external) and responds to any alarms that may go off. The officer also closely monitors the pilot's navigation so as to double-check that everything is correct. In most of these ships the bridge team uses closed-loop communication; before performing a course change the pilot will say for instance 'starboard [to course] 213', and the officer replies the same if he believes the turn is correct and on time. All changes to ship controls are communicated in this way.

The navigational and safety demands on these ships are so high that it is hardly possible to work onboard without thorough preparation. One common way of introducing new officers to the ships is to use a couple of days of overlap with the previous officer. Later, as time passes and new officers start to be familiar with the ship and its systems, they may be asked if they are interested in studying for a pilot's exemption. This is usually a joint judgement by the existing pilots and captains. We must remember that officers who decide to become pilots are not new to navigation, or to the waters. They have travelled them many times, progressively learning more. As an officer and pilot, K, says: "*The reporting points are learned at no cost*" (17P-16). He means that the names are learned as you report on the radio to the VTS (Vessel Traffic Services) station that you are passing these points. A further help in learning is a passage plan printed out for each trip, in which planned times of passing these points are printed, and the actual times are filled in by the officer of the watch. One officer tells us after having spent about a week on board that the more you work the more you realise how much there is to learn; in the beginning he thought he would

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manage easily and in a relatively short time, but he soon realised how much there really was to learn (7P-448-451).

For example, they have to learn the courses to steer – about 50 courses for the typical Stockholm archipelago route, one way. These courses are a kind of 'ideal case' or a guide, and are pre-programmed into the autopilot system. The courses are also learned through practice, by being a watch officer. But, according to the pilot N: "*to get further you have to start looking actively for information*" (17P-626-628). What this means is a pilot trainee will have to search the charts for information, the radar image for good landmarks, and learn how the wind affects the ship's manoeuvring (especially turning) abilities – including how to correct for this. The specific details of piloting, in reference to the particular ship and the voyages one has taken start to become important, and are slowly compiled into a book, the course book.

5. THE COURSE BOOK: HOW MARINERS LEARN THE ROUTE. A course book is a personal file containing copies of charts, on A4 sized paper. The charts show the route and its immediate surroundings. In the Stockholm archipelago, they cover about 55 nautical miles. These copies do not originally contain much of the information found in a normal sea chart. They contain latitude and longitude scales, land contours, often names of islands, a few aids to navigation and a few shallow spots. The officer has to fill in anything he finds relevant to piloting the ship through the archipelago. The final result is a complete course book of the trip, which will be examined by the examining board, and then kept onboard in the future. The second part of the theoretical test consists of filling in the 'blind' charts (as they are called, see Figure 5), to which we will return later.

To give an example of how the course book gets built: the courses and reporting points are more or less learned as a watch officer, and thus put in. Another important group of measurements are turning marks and distances. A turning mark shows when to start a turn, and in order to construct them the officer searches for and measures distances to islands or landmarks, often ahead of the vessel. This distance is normally combined with a bearing to some prominent feature. These numbers are entered into the course book, showing which landmark they refer to and when the turn should start. For an example, see Figure 3, which is a copy of a course book showing part of the fairway in Figure 1. In the lower left quadrant there are numbers for a turn to course 349 degrees, with a dashed line (bearing 349 degrees) indicating when to start the turn – when the line (on the radar) touches the small islet. The turn radius (Gr) is 0·45 nautical miles (lower right). There is an extra check in this chart, the distance 0·11 (lower middle) to a point on the island on the right side. More than one turn radius for the same turn may be put on a chart. Using different radii depends mostly on the wind direction and strength and with experience pilots learn how to compensate for various weather and sea conditions.

The above trip of 55 nautical miles consists of about 50 different courses, which means the pilot must know data for about 100 turning points (bearing, distance and turn radius; both ways), associated check marks and safety marks. Because of the high number of turn marks, at the beginning of learning "easy" measurements are chosen, e.g., "*if you are going to 050 degrees here, you find a distance of 0·5 miles, and*

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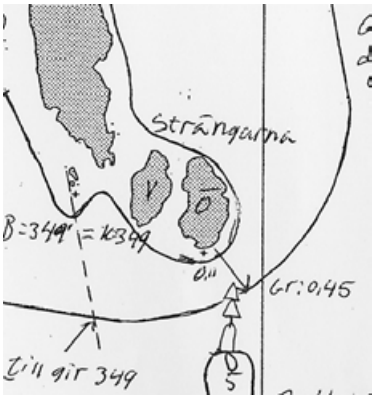


Figure 3. Section of course book showing a turn mark.

then you have the same …" (17P-349-353). Some officers choose measurements that are easy to remember for idiosyncratic reasons, like birthdates and other groupings. N chooses: "*… some turn or turning distance which fits me and is easy to remember, 0.[00] distance because I'm born on the [00]th, easy to remember, you look for those, there are so many turning distances on this stretch that you can't use different ones everywhere. 0·30 is one that's used in many places, 1·05 is in three places, you remember that too* '*there, there, and there*' *…*" (10P-p6).

Further measurements that get put in are safe distances from landmarks that demarcate the navigable water for the ship. Even if the ship usually follows the same courses every day, the pilots need to know how far from these courses they may take the ship if necessary (how close to land). One constraint in building the course book is finding appropriate places to place your measurements on. T explains: "*When you make your course book you choose your own distances in some cases; how do you choose them? You need a distance to something which is close to 90 degrees from your next course, put out the EBL and see what fits*" (15P-373-378).

They need to find an island or landmark not too far away on either side of the course. This is done by moving a line parallel to the course line until it touches an appropriate landmark. When good fits (islands, points) are found, the distance between the course line and its parallel is measured and used as a safety limit, to show the limits of a safe passage. The line and the distance to it comprise the *parallel index* (Westwood, 2005). Two distances to the landmark, a maximum and minimum one, provides a safety envelope, or safe water (see also Olsson, Seipel, & Jansson, 2002).

In Figure 4 we give an example: the course line crosses the upper half of the figure and is marked 278/098, which are the courses to steer in either direction. 90 degrees from it an arrow marked 0,25 and 0,15 is seen. This is the maximum and minimum distance from the landmark for a ship to be in safe water. The landmark is a small island to the south. This line and the distances are the parallel index for this course. When using this to pilot, an electronic bearing line (EBL) is placed on the radar screen bearing 098 degrees, at 0·25 nautical miles from the own ship. As long as this line slides along the top of the island, the ship is on the right course *and* safe from the 5-metre ground denoted north of the island. It is possible to come as close as

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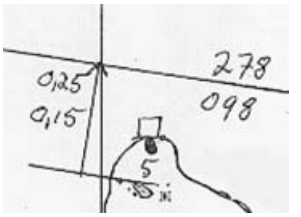


Figure 4. Parallel index in section of course book.

0·15 miles if necessary. This particular line can only be used when they are close to this island, so they have to know scores of parallel index measurements for the trip. For every course there is at least one parallel index, and thus, they too number in the hundreds. All the numbers mentioned were drawn into the course book by the pilot-to-be.

The line-finding is usually performed on the radar, as that is where the lines will be used. Furthermore, the pilot knows what the chosen landmark looks like in the radar, instead of measuring on the paper chart and finding out the chosen spot is distorted on the radar image. The speed of the ship makes it hard to build all indexes on one trip, as one goes along. This means that many trips are needed to build a 'complete' set of indexes.

The building of the course book is supported by individual and social learning. Individual learning often takes place in solitude, as one officer tells us: "*I spent many hours in my basement poring over charts*". The social learning takes place as various pilots contribute to the learner's strategies, the data he chooses to use and how it is inscribed in the course book. When starting out, the officers work with many experienced pilots and learn and take tips from them for compiling their course book data. It is very common to hear a pilot saying to an officer: "*I've got a good mark here, it's xxx to that point there*". A good mark is one that helps them navigate safely, i.e., see it easily on the radar, and one that is easy to remember. Pilots talk about other pilots' marks: "*is that XX's way?*' – '*no it's YY's*". The course book is slowly filled in, and becomes a record of the entire trip through the archipelago.

The book becomes an amalgam of data, from charts, personal experience, idiosyncratic associations and groupings, and information from other pilots. The chart is slowly becoming learned, and the course book becomes an anchor for all the knowledge and experience related to driving. At the same time, details are being learned that are not explicitly represented in the book, or the chart. With more experience of driving in various traffic and weather conditions, measurements get refined, and the ability to adapt turning distances and turning radii to weather conditions grows. Navigators move from a static and stable representation to a useful representation for piloting. This will be further discussed in section 7, 'Pulling it all together'.

The course book is a mediating structure, which is used for remembering, referencing and planning. It is always kept close, on the bridge and very often immediately at hand next to the pilot's seat. It is similar to the 'black book' of many professionals. On the other hand, the book rarely changes after the examination (some officers say). Even though marks do change since better ones are found as expertise grows, not many of these changes find their way into the course book. The 'mental chart' and

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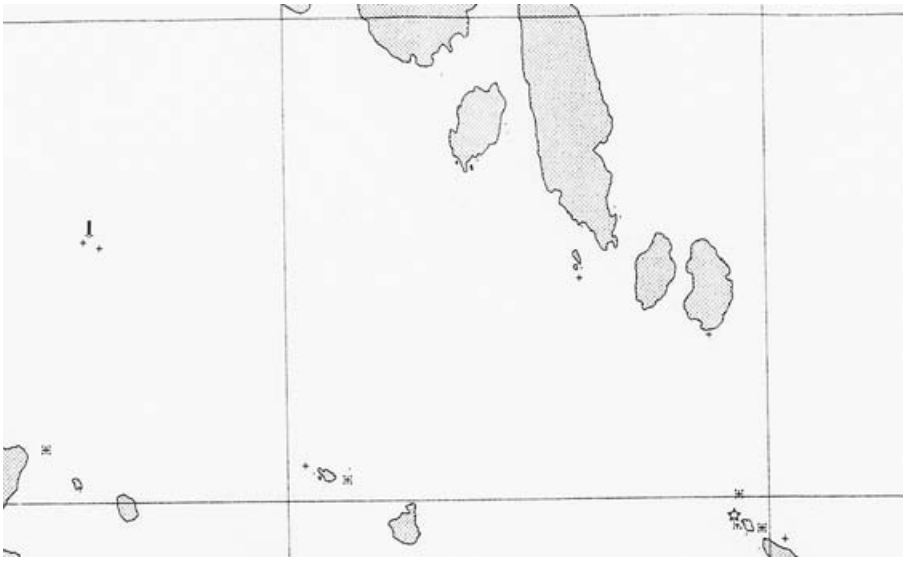


Figure 5. Section of chart for course book.

the course book chart diverge more and more as marks are refined, in short as officers or pilots gain more experience and competence. We turn now to the next part of the training: learning and being examined on the geography.

6. THE BLIND CHART: FILLING IN THE BLANKS. For this part of the examination the pilot-to-be is given a practically blank chart, see Figure 5. All that is on it is land contours, a few aids to navigation such as a spar buoy (a line with a ring below, middle left), a lighthouse (lower right, the star symbol) and a few shallow areas (4 dots around a plus-sign). The officer essentially has to remember and draw in all he has put in his course book. This particular chart shows part of the Stockholm archipelago and is a small part of one of 11 charts for this particular route. This part of the blind chart corresponds to the filled-in one in Figure 6 and the chart section in Figure 2. Beyond what has been learned before – reporting points, courses, turning marks and parallel indexes – the examinee has to know and to fill in names of islands and waters, fairways (including indications of crossing fairways), speed limitations, buoys, lighthouses, points, depths, lighthouse characters. He must also know the approximate positions of navigational aids.

There is a great deal of information that has to be remembered, in order to pass the exam and to be able to pilot a ship through these waters. Part of the training or learning is done by cramming (brute force memorisation), and a system is often used by candidates, in which groups or sets of data is learned in turn. S starts with the courses, and will later go on to other data: "*I drive all the time, on the Finnish side without a radar chart, studying courses [course lines] in my cabin, then I'll learn the buoys etc … it's like stuffing a sausage*" (11P-8-9). S further tells us how frustrated he was when he began to study for this examination: "*If I hadn't known my colleagues had done it I would have given up*" (15P-457-466). The cramming or stuffing is a long

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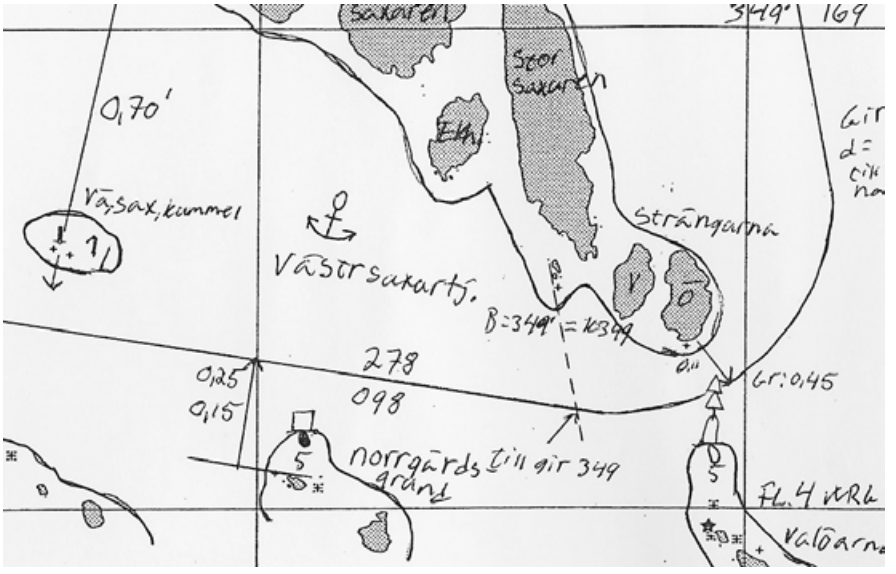


Figure 6. Section of filled-in course book.

process, in which they also work a lot by association. This is done either by choosing numbers that are similar, or constructing other types of *aides memoires* like chains of numbers. K and N discuss this:

N: "*when you're studying, you try to find associations*"
K: "*yes, make links, 7-5-7-3 to remember for instance depths at a certain place*"
N: "*if the course is 125 the depth may be 2·5, you have to build associations*" (17P-623-625).

N makes associations by finding similar numbers and K talks about chains or 'links' of numbers to be memorised. Officers also make verses or nonsense sentences to remember sets of names for island groups. This is a common way of remembering in many professions: physicians often learn human anatomy this way. Furthermore, the officers use their surroundings to help them remember as G, another officer points out of the window and says: "*Over there is Gråholmen [Grey island], it's not grey but I remember it because across from it there are two islands with a lot of dead trees, that look kind of grey*" (17P-200-202).

They tell us about the difficult Finnish names, some of which are hard to pronounce for a Swedish person. One officer says: "*the names on the Swedish side are quite comfortable [to pronounce], on the Finnish side it's hopeless …*" (O7-p10). Some of the difficult names are shortened or given 'pet' names that make them easier to remember or associate to. For example, a place named Kaasluoto is called 'Kasan' which resembles the Swedish word 'kasa' which means 'slide'. S explains: "*you sort of slide down there … that's how I remember it*" (12P-248-249).

Some of these associations may be forgotten when the name is learned, but many of these 'silly' associations are remembered for life. It is not entirely clear to the officers how much they have to know and remember for these examinations, which is a constant 'worry'. S is training for the examination and looks at a distance someone

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else wrote on a chart, and says to A, the pilot: S: "*… it could be good to know for the test, I wonder how demanding they are on the test?*" A: "*oh, very demanding*" (13P-148-149).

When the exam day draws close, the pressure mounts. K says: "*in the last three weeks I would spend three hours a day [drawing charts]*" (17P-179-183). The officers take many copies of the blind charts and practise filling them in. K explains further his method: "*well you take one at a time and try to finish it, then the next, go back and check the mistakes on the first, then a third … and then number one again … you add one all the time … I think you have to [do it like this] so you keep remembering the old …*"(17P-188-197).

All this information is not learned in isolation from other activities. Most of it is learned through 'learning in use', and associations are not solitary isolated chains of information, but most of them are learned and remembered through driving, checking and turning. In this way officers begin to learn how to transform geographic and cartographic representations into models and scripts that enable them to pilot with competence and confidence.

7. PULLING IT ALL TOGETHER. Pulling all the data and experience together is an ongoing process. As time passes the details of the course book and charts get memorised. The officer practices driving, both in reality together with different pilots, perhaps in a simulator and in his mind. In all of this, static details become linked to a dynamic world, when numbers turn into useful boundaries and when dry data are transformed into a plan for action. Here, we will discuss how this plan for action is constructed and what it consists of. The examples below illustrate this linking between practice, geography and piloting.

When C learns he looks at something they pass, for instance a skerry, checks it against the radar and then against the chart: "*OK, that was xx*"(4P-81-82). Bridge work then can change the literal model, the 'simple' chart, into a useful representation for piloting.

Another officer tells us how he constructed and learned the parallel indexes for the trip:

> S: "*now that I'm training I use parallel index, absolutely [I have to] or I haven't got a chance … on the earlier shifts I've been choosing what I thought was appropriate points [of land] to put the line on, and then I have to measure the distance to the track, then I just have to start pounding it in, driving on it, learning this picture by heart …*" (13P-122-128).

S tells us about the stepwise and intertwined process of learning: he chose appropriate points of land on earlier shifts, he is now measuring the distance to them on the radar, and he will later learn them by heart. This is for candidates a move from the literal chart via course books and blind examination charts to a personal chart they use to pilot the ship. This personal chart is not a tangible artefact but a kind of personal construct. What is important to stress here is that the practice of driving very directly informs chart learning, whether in the real world or in the mind. Part of the learning process is mental simulation of driving, as an SMA pilot tells us about how he trained for his exam: "*I used to drive in my head before I went to sleep. I used to make it some distance … and go through all the stuff on the chart for that stretch. If it didn't go well I would drive it again the following night*" (O7-p2). He is not only

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mentally driving, but also goes through all the details he must know for the stretch of water. This kind of training has elsewhere been called mental rehearsal or imagery, and it has been shown to facilitate the performance of complex tasks (Klein & Crandall, 1995). It is not clear, however, how often mental rehearsal has been shown to include both imagining an environment in detail *and* navigating through it.

When driving in the real world, very often small corrections or amendments to the basic courses are required to compensate for wind, sea or traffic conditions. Learning how to vary the courses and turning parameters are part of becoming an expert and needed to become a pilot. The variations are best learned by practical driving, together with an experienced pilot giving guidance. One example of a dynamic aspect is the hydrodynamics of the passage. In very narrow straits the speed of the ship in conjunction with the shallow and narrow water will cause the ship to veer due to suction effects, called squat (shallow water) and bank effects (narrow channels). The navigators learn about this, when the suction 'hits', how strongly, and when they can expect it to 'let up', so that they can apply counter rudder to keep their course. These suction effects can change several times during the passage of a narrow strait, but are often the same for the strait as a whole. This excerpt exemplifies that learning, where S is learning to drive and A is helping him:

S: "*should I let her [the ship] go to 267 or should I meet [use counter rudder] … where is the last suction in here?*"
A: "*the suction will start soon so you start coming to port here, so now you can almost set it to 270 degrees, I should think that it … yes*"
S: "*I'm home now?*" [clear/finished]
A: "*yes you're home now, make the turn when you feel like it … it doesn't matter as soon as you're clear of this buoy, the course change is so small*"
S: "*it would be interesting to know if there is any more suction to come?*"
A: "*no, I, yes … it depends … you are actually getting some suction here … but it will let go soon*"
S: " *… hmmm … you really have to train a lot at this …* "(7P-304-315).

In the discussion we see S asking questions about the suction and when to counter it and A answering them, and making it clear how suction effects are sometimes hard to predict, as we see at the end. These dynamics are not entered into any chart or book, but are learned through experience, driving and from other pilots. And with time it improves, as S and A tell the first author after S has just negotiated another strait:

S: " *… that was better [a turn just finished] … a little smoother?*"
A: "*I must say, it was incredibly good … yesterday he [S] turned a little bit too early, but today he waited … until the suction let go … then he turned and it was perfect as you can see …* "(7P-279-287).

Practice makes perfect, and we see S's competence increasing. Also, they learn about the place, not only how to manoeuvre through it. As one officer tells us: O: "*when you've been to a place a couple of times, you know it.*" (17P-634-635). The personal chart works even without contact with the physical world as we saw from the pilot who practised driving in his head before going to sleep. Even when it has not been used for some time it can be recalled and is cued, at least in part, by seeing the anchor points. The pilot A tells us that when they were driving in a place they

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had not been for many years all the courses and turning marks came back to him (11P-115-116).

The memories of place and anchors "come back" and help to make sense of the inner and outer in respect to each other. Expert navigators and pilots can also "work" a personal chart even when there is imperfect "fit" between place and chart. Even if a personal chart fails a pilot or navigator, they can often handle it. We have found two conditions when personal chart and plan and ship can essentially disconnect, one when plan and reality don't "look" like each other anymore, the other when plan and reality become out of synchronisation with each other. The first is due to poor weather conditions, especially snow or snow on ice, as the pilot N explains: "*With snow and ice, you see only the trees not the contours of the islands, optical marks are less visible. You have visibility but you don't see, not what you want to see. You have learnt a picture of the landscape, and when it's light out and snow, everything is white you just see trees. You don't see what you expect; you might as well pull down the blinds. You don't recognise yourself but you know where you are*" (16P-12-15).

N has an internal 'picture' of what he expects to see, and in this case he would rather not even look outside as he cannot make that view fit his 'picture'. He finds it disturbing for a while, until he after a few trips gets used to the 'new' look of the world. Other officers claim to mostly navigate by radar and seldom use the view out of the window, and are not so disturbed. What makes the difference is which parts and resources you include in your plan-for-action, how you represent them and compile them for yourself. If you look out of the window, there is more data, which can be good (good redundancy). But it is another element that has to be merged into your plan, and if this represents hard work and takes you away from the task at hand this could be bad redundancy.

The second condition is when a personal chart lags behind what current conditions are. This is particularly an issue for novices. It is harder to update and revise personal charts and plans for novices who still build them in a relatively naïve fashion. In short, they still stay close to and work with only literal geographical and cartographic representations. The pilot N is training and teaching a new officer, who has been onboard a short time. The officer is driving and N is monitoring him. They have just performed a turn, which the pilot feels could have been a little different. N: "*Think like this … if there's a wind and it's restricted waters, then you easily end up having to use 10-degree course changes to get where you thought [want], then the whole picture disappears when you drive, these turn controls [measurements], leading lines, everything is like gone … they have … you didn't do anything wrong, it's just that the more you drive …*"(9P-p9).

The 10-degree changes N talks about as something you do not want to make use of. It is an example of the small margins in the archipelago and in the personal chart, the kind of representations novices have to take into account. If a novice is getting too far from the course, he may feel he wants to apply a large course change to correct the situation. Large course changes or corrections may cause the ship to move further than wanted and then counter rudder has to be applied, also perhaps a little too much. The ship then starts turning faster and further than expected and wanted and ends up oscillating across the track.

If the ship is not on the intended track, the course change marks may not be as useful. One recourse is just keeping within the 'safe waters' by resorting to using parallel index. To update and navigate by these mechanisms under sail represents

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considerable "load". The more a novice drives the less he has to resort to "primitive" representations as he works towards expertise. Several traits characterize expert pilots. First, they have considerable memory of place and can apply this to present situations in a way novices can not. Second, in reference to the physical world, they have acquired series of anchors, anchors derived from prior experience and prior history of working these waters. In effect then competence here often implies the ability to make sense (and plans) out of less than accurate or even incompatible representations of information. Thirdly, they know how external forces influence the ship and how this can be countered or even used to their advantage. Some officers for instance talk about using the wind as a resource when turning. An important attribute of competence is how experts pull all this together, as N tells us:

Q: "*is it experience of the environment or the [technical] system?*"
N: "*it's a combination, you learn how the system works … in a large turn, in combination with drift and winds … no computer could ever do that … the whole job, all the time …*"(7P433-436).

What N describes is the combination of chart knowledge, in-the-world proficiency and experience, which becomes a personal chart. In the following section we will discuss how this transition takes place, and connect to relevant literature.

8. DISCUSSION. According to Lave, changes in knowledge and action are central to learning (Lave, 1996). What we see these pilots doing during learning is precisely this, changing their knowledge and their actions. We also see how large parts of the learning is situated activity – learning in context. All environments are of course contexts in their own right, as for example the basement where one studies charts, but when we discuss situated activity here we mean the shipboard practice of piloting and driving. We see how this context informs and constrains learning, by environmental and social factors. As many researchers have shown context is used by learners to assist them in learning (Brown, Collins, & Duguid, 1989; Lave, 1996; Säljö, 2000).

Over time the officers incorporate a substantial amount of data, transform it into meaningful and useful charts and plans, and integrate this with practical driving skills. These data are not all 'maplike' in their form, and Tversky terms such a combination a cognitive collage rather than a cognitive map (Tversky, 1993). Cognitive collages are typical of environments that are not known in detail. When experience is gained from an environment so that it is well learned, she suggests that people have more accurate mental representations, called spatial mental models. From what we have seen, it is possible that officers start out with a cognitive collage, which as the environment is learned is transformed into a spatial mental model. But there is more to this than a mental model, as many of the ingredients from the collage are still used, and integrated into the 'model'. Also this concept tends to neglect the role that planning and skill have in the model, what the model represents and how the model gets translated into action. This is evident in studies of spatial knowledge and navigation, which tend to sharply divide studies into knowledge acquired from maps *or* navigation and abhor attempts to combine them (e.g., Thorndyke & Hayes-Roth, 1982).

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Tversky (2003, p2) addresses another navigational dichotomy, when describing how research on spatial cognition has been divided into two: "the mind community [wants to] reveal the systems generating error and … the body community [wants to] reveal the systems generating precision". Furthermore, she argues that what is seen as errors are in fact consequences of ordinary perceptual and cognitive processes. When she describes how people "schematize" (simplify, approximate and omit) information into collages, we see the personal chart as a stepwise moving from simplified cognitive collages, which transform and are filled out, refined and tuned with time. The personal chart is a construction geared towards appropriate action. Such a representation is not an internal copy of the world but a useful action-oriented construction, and in this case many and precise details about the world are represented.

Furthermore, another part of the personal chart or construct is action which becomes part of the representation, both in building it and maintaining and "improving" it. The personal chart is built up through the transformation of parts of world models (charts), visual input from windows and radar screen, mathematical procedures, memorising and kinetic feedback loops. This integration across modalities (Tversky, 2003) results in a plan-for-action. Suchman defines plans as both a resource for action and explanation, and emphasises how a plan is but one of the features that shape our responses to situations (Suchman, 1987). Since navigation and piloting is mostly about positioning, here, the plan is used to figure out where to go, but also to afterwards evaluate where they were and if that was good or bad and how it could be done even better. What we term experience bridges any number of analytic gaps or disconnections that for the mariner in practice is seamless and represents no disconnection.

Gullers reminds us that professional knowledge is not the same as having a manual skill (Gullers, 1988). Even if it were possible to automate manual skills, most systems need to incorporate professional knowledge – something that designers and developers have not found easy to do. Again training includes apprenticeship. S says: "*when I came here I was told I should have it in the hand and in the head … not leave it to the technology*" (6P 32-33).

The work strategies change over time; some of what the officers once learned may not be used often. Parallel indexes are one example of this. Some pilots continue to use them as an extra safety check but not many pilots do this. The indexes are available in the course book if needed. After their examinations, pilots for the most part use the radar chart, in which the pre-programmed track is used, the 'ideal courses'. The most common reason cited for using information they may not have used in some time is when they have to navigate alternative routes, routes they have learned once, but seldom use. This could be due to ice conditions or surprise meetings with other ships or manoeuvres to avoid close quarters situations of some kind. In the summertime the overabundance of leisure craft, sometimes manned by less skilled part-time sailors, may cause the ferries to have to make use of all the safe waters they have available.

The mariners studied here construct a dynamic chart, in many aspects bound to the particulars of the specific ship. Several observations merge here; radar, window, chart and kinetics. The resulting representation becomes a basis for a model for planning and action. The strategies an officer uses will structure not only the information he values and uses but how it is built up into his representations (internal and external)

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and how he applies both to navigation, getting the job done. In some instances the officers say, I don't rely on the outside view, I can drive with radar only. Others say they look out too, and they know what they expect to see. There are different strategies, but all similarly useful, it seems.

The movement from model to experience and back again never seems to stop. Nor does the accumulation of knowledge and information. What we have here (as in most skilled professional work) is a never-ending process. Learning continues throughout an officer's career. E: "*you're never fully learned, you learn all the time, you keep comparing to the chart*" (3A-161-163). The officers learn during the time as a pilot's trainee, and when they have their exemption, they get apprentices of their own to instruct. Sometimes an apprentice brings measurements he has gotten from another pilot and they discuss them, which can make the pilots reflect on their own marks and sometimes change them. Thus, the learning process is continuous, even if the refinements are not recorded in the course book.

9. CONCLUSIONS. What this paper presents is a study of how over time both representations (map) and the meanings they have are transformed through practice. Further we have traced out how the notion of practice itself changes over time, and how the representations and the meanings that support this work change too. What we have found with these mariners is that memory is neither static nor unimportant. Rather memory can be profoundly transformative and its use in bridge work demonstrates this. With these officers what was once a literal model (map) of the world changes over time. Cross referencing between the world, chart and course book allows these pilots to build up, through experience, a model that allows them to get the job done. It helps them answer the question that informs almost all bridge work, 'what do we need to do next?' It is the anticipatory nature of the representations mariners build, use and come to rely on in the archipelago that raises questions for us in the human factors community. There is a need for further research into both how our informants make use of models in their work and into how the human factors community has so far linked together model, representation, competence and work.

There is another related issue. It is evident from this study that both learning and practice continue over a pilot's career and learning and working mutually inform each other. The idea of work and learning as iterative is commonplace in the human factors literature. Nevertheless, working and learning are often handled in design and development agendas as separate processes – not as they occur in the workplace. As we have shown, from the operator's point of view these processes are not easily split apart. The question then is what we may have lost by essentially designing, building and thinking more in our terms than our informants. There is no simple answer to this. But this does raise questions about the kinds of questions we need to ask when we talk about the connections we make (and our operators make) between representation, work and experience.

What we hope we have done here is given the maritime community and other readers a close reading of what it means to do (and to learn how to) driving and piloting. We hope too that this paper demonstrates the worth ethnography can have illuminating complex professional work and in so doing bringing to the human factors community attention a series of important issues.

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