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Evaluation of eye-tracking as support in simulator training for maritime pilots

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SUMMARY

The Swedish Maritime Administration provides maritime pilotage when vessels operate in Swedish pilotage-obliged water. Through the maritime pilot's knowledge of the waterways and experience of maneuvering different types of vessels, the pilot contributes to ensure that maritime and environmental safety as well as accessibility can be maintained. In addition to skills in ship maneuvering, navigation and seamanship, the ability to interact with various types of technology, cultures and crews is also required. Each ship is unique in terms of propulsion, steering, navigation, and communication equipment as well as maneuvering and information instruments. With increased levels of automation, the demands on maritime pilots to interpret, understand and handle technology are increasing. Today, the maritime pilot training is based on a long tradition of apprenticeship, where the pilot's competence can be seen as implicit (tacit) knowledge developed through years of experience at sea. But, since the maritime pilot profession is a practice in change, it puts higher demands on the pilot training. One step is to find out the experienced maritime pilots' valuable tacit knowledge and transfer this to the next generation. Another step is to include new technology in teaching activities, such as using eye-tracking in simulator training.

The purpose of this multidisciplinary research project was to investigate what it means to be a professionally competent maritime pilot, and how current training practitioners are organized for pilot students to develop professional competence. Also, how the training can be further developed to achieve improved quality.

The following research questions have been answered:

(1) What are the strengths and weaknesses of today's simulator maritime pilot training?
(2) What methods can be used to find tacit knowledge and visual expertise from experienced pilots useful in the pilot training?
(3) What didactic methods and technical support can be used to transfer tacit knowledge and visual expertise efficiently and reliably from experienced pilots to pilot students?
(4) What needs for technical and didactical competence development do instructors require when implementing new technology in the pilot training?

The research questions were answered through four empirical studies:

(1) Mapping strengths, weaknesses, and challenges in today's pilot training. Special focus was on exploring aspects of the pilot's tacit knowledge.
(2) Studying how the pilot's visual expertise develops within and through social interaction during simulator-based activities in the pilot training. If and how is the simulator environment a realistic and relevant training context for pilots.
(3) Exploration of eye movement patterns in experienced pilots and pilot students.
(4) Evaluation of how instructors can interpret and use data from eye-tracking as a basis for training and assessment of pilot students.

The overall results from the research project have contributed to an increased understanding of how challenges and opportunities in today's maritime pilot training can be met with the help of new didactical and technical approaches in simulator training. The project has also generated recommendations and measures for how professional knowledge can be trained and assessed through participation in simulator environments.

The specified results about using eye-tracking as a didactic tool, and facilitator of tacit knowledge transfer in simulator based maritime pilot training are:

Eye-tracking

- Eye-tracking is usable as a support during the simulator training in the Pilot Training Program (PTP) in terms of visualizing attention, scanning, gaze behavior, and as a mean to support simulator session briefings.
- A systematic implementation of eye-tracking in terms of establishing pedagogical and didactical documentation is required to reach set training objectives.
- Effective utilization of eye-tracking requires considerable resources in terms of time, equipment, infrastructure, staff, and training of staff by the PTP organization.
- Physiological prerequisites among participants such as corrected vison and head posture requires mitigation.
- Using eye-tracking to assess collaborative task performance lacks a specific methodology.
- Links between visual attention, cognition, and learning are not clear and require more research.

Tacit knowledge transfer

- The reproduction of pilots' tacit knowledge was not found during the simulator part of the PTP, except during the part dealing with Marine Resource Management (MRM) training.
- It is ambiguous if the reproduction of specific pilot skills is based on tacit knowledge transfer or on development of know-how (using volume training) combined with pattern recognition over time (experiences from different vessels on the same waterway).
- Pilot specific skills such as controlled navigation, ships handling, and hydrodynamics were initially regarded as plausible tacit knowledge nodes but were subsequently assessed as generic for any Master.
- Using volume training, pilot specific skills were systematically trained to a higher standard.
- Developing pilot specific skills are in terms of guided experiences during apprenticeship predominantly located at the Local Training Plan (LTP) part of the PTP.
- Identified tacit knowledge transfer events may contain more of articulated rules, procedures, or operational descriptions than tacit knowledge.

RESEARCH RESULTS - PUBLICATIONS

The results from the theoretical and empirical studies completed in the research project are presented in eleven publications, enclosed in this report.

- Eight scientific conference papers, followed by slide-presentations (No. 1-8)
- Two conference abstracts with slide presentations (No. 9-10)
- Conference session: **Human Factors in Transportation: Maritime track** including five abstracts followed by slide-presentations (No. 11:1-5)

1. Eklund, E., Sellberg, C. & Osvalder, A-L. (2020). ***From Tacit Knowledge to Visual Expertise: Eye-Tracking Support in Maritime Education and Training***. In: Nazir, s (eds) Advances in Human Factors in Training, Education and Learning Sciences, AHFE 2020, AISC 1211, pp. 269–275, Springer 2020. https://doi.org/10.1007/978-3-030-50896-8_39

2. Sellberg, C., Praetorius, G. & Nivalla, M. (2022). ***Eye-Tracking in Simulator Training and Assessment: A Semi-Structured Meta-Review***. In: Salman Nazir (eds) Training, Education, and Learning Sciences. AHFE (2022) International Conference. AHFE Open Access, vol 59. AHFE International, USA. http://doi.org/10.54941/ahfe1002416

3. Eklund, E., & Osvalder, A-L. (2022). ***Transferring Tacit Knowledge During Maritime Pilot Training: Assessment of Methods in Use*** In: Katie Plant and Gesa Praetorius (eds) Human Factors in Transportation. AHFE (2022) International Conference. AHFE Open Access, vol 60. AHFE International, USA. http://doi.org/10.54941/ahfe1002503

4. Praetorius, G. & Sellberg, C. (2022). ***Eye-Tracking in Simulator Training and Assessment: A Semi-Structured Meta-Review***. Advances in Transportation, Vol. 60, 2022, 657–664. *https://doi.org/10.54941/ahfe1002502*

5. Eklund, E., & Osvalder, A-L. (2022). ***Assessing non-technical methods for transferring tacit knowledge in safety critical systems: A study on maritime pilot training***. INTED2022, Valecia, Spain, March 2022. Proceedings, pp. 9908-9914 https://library.iated.org/view/EKLUND2022ASS

6. Sellberg, C & Säljö, R. (2020). ***Developing visual expertise in a simulated environment: A case of maritime pilots in training.*** 2023 American Educational Research Association Annual Meeting (AERA2023), Chicago USA, April, 2023.

7. Berlin, C. & Praetorius, G. (2023). ***Applied Cognitive Task Analysis (ACTA) of marine piloting in a Swedish Context.*** 14th International Conference on Applied Human Factors and Ergonomics (AHFE 2023), San Francisco, July 2023

8. Eklund, E., & Osvalder, A-L. (2023). ***To sea, or not to sea, that is the question: Evaluating eye-tracking as a didactical tool and facilitator of tacit knowledge transfer in simulator based maritime pilot training***. WMU (World Maritime University) Journal of Maritime Affairs (Submitted 2023).

9. Sellberg, C. (2022). ***Full-mission simulation training risk factors (and how to avoid them).*** Conference keynote presentation. Nautical Institute 50-year Anniversary. Organizer: The South African Branch of the Nautical Institute, October 2022.

10. Osvalder, A-L. & Eklund, R. (2022). ***Transferring tacit knowledge among operators in safety-critical systems.*** Abstract at the Nordic Ergonomics & Human Factors Society Conference 2022, October 23-25, Uppsala, Sweden.

11. Panel Session AHFE Conference (2023). ***Eye-Tracking as Instructor Support in Professional Education and Training: Findings from a Cooperation Between Research and Practice***. *14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences.* San Francisco, 20-23 July, 2023.
https://openaccess.cms-conferences.org

RESEARCH REPORT 1

From Tacit Knowledge to Visual Expertise: Eye-Tracking Support in Maritime Education and Training

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From Tacit Knowledge to Visual Expertise: Eye-Tracking Support in Maritime Education and Training

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Abstract. The maritime pilot is an expert with knowledge on a specific navigational route. The maritime pilot cadet undergoes maritime education and training in classrooms, onboard vessels and in simulators. Developing visual expertise is a basic objective. Transferring knowledge from experienced maritime pilots to maritime pilot cadets is challenging since some of this knowledge is tacit. The transference is achieved by externalization and socialization processes. The objective of this pre-study was to assess eye-tracking methodology as a tool to support maritime education and training, and for transferring tacit knowledge. The study was performed in an explorative way during simulator sessions, by interviews, questionnaires and observations. The result shows that eye-tracking methodology is useful for transferring tacit knowledge in simulator settings, but not during other parts of the education and training. The results also show that situational awareness of maritime pilot instructors and maritime pilot cadets increases when utilizing eye-tracking methodology.

Keywords: Maritime education and training · Maritime pilot · Simulator · Eye-tracking · Visual expertise · Tacit knowledge

1 Introduction

The maritime pilot (hereafter pilot) guides vessels in order to maintain safety, protect the environment and to ensure availability of harbors. The Swedish Maritime Administration provides pilotage and assistance in the navigation to vessels within Swedish territorial waters. On average, 32.500 pilotages are conducted each year in Sweden [1]. When the pilot has boarded a vessel, the pilot will temporarily become a member of the bridge crew assisting the Master in command of the vessel with information and advice on the route to be navigated. Pilots are also able to provide effective communication with personnel on shore, such as Vessel Traffic Service Officers and crews on tugs. While the Master always remains in command on the vessel, the pilot conveys expert knowledge and may maneuver the vessel if agreed upon [1]. The working practice of pilots is by tradition still to large extents relying on the pilots' visual outlook on the maritime environment, in combination with semi-automated systems for communication,

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navigation and surveillance [2]. The Portable Pilot Unit (PPU) is carried onboard by the pilot and is a support-tool that assists the pilot in performing safe navigation of the piloted vessel. The pilots' working situation is part of a larger safety-critical socio-technical system [3].

The pilot is required to master two skills: ship handling and having expert knowledge on the specific route in terms of area geography, infrastructure, navigation, and oceanic as well as meteorological particularities. Ship handling is generally acquired during extensive sea going experience as a Master; expert knowledge is acquired during maritime education and training (MET) provided by a Competent Pilotage Authority (CPA). In Sweden, the CPA is the Swedish Maritime Administration. The maritime pilot cadet (hereafter cadet) undergoes MET in classrooms, using scale models, simulators and supervised pilotage training on waterways during a period of 6–12 months, in combination with formal and informal interaction with senior pilots at the pilotage station. During this process, simulators offer opportunities for cadets to train and evaluate work practices and strategies in an educational setting. Using simulators, scenarios can be specifically set up and adjusted to match requirements. The simulator also allows the cadet to gain experience, partly by making errors and learn from these through evaluations of the actions taken. Scenarios can be repeated over time to present and train different actions and solutions, to illustrate potentional arising risks or to drill the cadet in basic maneuvers [4]. Sellberg [5] as well as Hontvedt and Arnseth [6] point out that a simulator does not add much per se in terms of learning; the advantage is found in how a scenario is simulated and how routine operations as well as critical situations are resolved in interaction between the participants.

1.1 Study Aim and Objectives

Teaching in a simulated maritime environment generates challenges for the maritime pilot instructor (hereafter instructor) to assess where the cadets keep their eye-focus. Analysis of eye-focus is a method to evaluate if attention is allocated at the right object, at the right time, and for the accurate amount of time [7]. In previous research, eye-tracking technology has been used for evaluating handling of equipment on ship bridges, as well as for observing interaction, attention, vigilance and situational awareness [8]. Eye-tracking focuses on tracking the position and movement of an eye, generating data that can be assessed, analyzed and visualized in specific software programs [8].

The objective of this explorative pre-initial study was to assess if the eye-tracking methodology is a useful tool to support tacit knowledge transfer from expert to novice pilots focusing on developing visual expertise. In particular, this study investigates if and how eye-tracking data can be useful for educational purposes in simulator-based MET of pilots, by investigating the following questions; (a) explore how the Swedish Maritime Administration conducts training of pilots, and (b) evaluate if eye-tracking can improve pilot training in terms of didactics and methodologies. Through this, eye tracking is (c) evaluated in terms of its usefulness as a tool to improve transfer of tacit knowledge when cadets develop their visual expertise and skills as pilots.

2 Background

There are many definitions of expertise: Karhu [9] implies that expertise is based on extensive knowledge; Gobet [10] extends the definition and defines an expert as someone who has a superior set of knowledge, expert opinion, know-how, or expertness in an area; Johnson et al. [11] define an expert as someone who is characterized by superior performance within a specific domain of activity; according to Dreyfus and Dreyfus [12] expertise is fluid, automatic behavior without any conscious control, and developing expertise also requires a significant amount of time. In the context of maritime piloting, the cadet has gained years of experience as a Master, which is a prerequisite to become a pilot. The transfer of knowledge, in order to acquire professional skills, is achieved by interacting with experienced pilots, by experiences from the actual pilotage route, as well as through simulator sessions and briefings during and after these sessions. Furthermore, reflection (in group settings or solitarily) is important to enable professional learning [6, 7].

Experts and novices use different strategies to gain knowledge. Based on experience, the novice develops improved strategies to better interact with the specific environment; strategies that over time becomes knowledge [13]. Kasarskis et al. [14] found that dwell times in experts are shorter than in novices, indicating that experts gather the required information quicker than novices. Experts and novices furthermore fixate given information differently, based on not only the available type of information but also regarding the most important information. Conducting maritime pilotage requires a high degree of visual attention, both inside as well as outside the ship bridge. As the level of automation has increased continuously, the navigation-, communication- and surveillance-system interfaces require increasing attention. A common practise on the ship bridge is to prioritize conditions permitting the outside view, with RADAR and with other electronic navigational support systems, such as ECDIS and various forms of communication/surveillance as the first choice in low visibility or darkness. The latter is also used as a support during good weather conditions. Brown [13] outlines how expertise can be divided into a theoretical or declarative part (knowing that) as well as a practical or procedural part (knowing how). The latter is related to Polyani and the topic of tacit knowledge [15, 16]. He stated the expression “we can know more than we can tell”, thus suggesting that expertise develop over time by learning how to do things. Furthermore, Von Krogh et al. [17] regard expertise as a specific category of tacit knowledge “emphasizing the uniqueness of a person’s knowledge”. Tacit knowledge is a valuable asset for an organization, but since it can be difficult to express, it is often hard to convey to others. Hence, establishing means to identify, collect, document and transfer tacit knowledge is important [18]. The transfer of tacit knowledge requires personal contacts, interaction, as well as closeness and trust between members in the organization. Nonaka and Takeuchi [19] suggest that socialization is the first of two ways of transferring tacit knowledge; the novice learns from an expert by imitating, observing and by training based on instructions where tacit knowledge is directly translated to explicit knowledge. The second way is when tacit knowledge is externalized; first to explicit knowledge and then it is possible for the novice to assess it from oral presentation or documentation. Methods on how tacit knowledge can be transferred from experienced operators in process control have been proposed by Osvalder and Colmsjö [20]. Socialization can occur in shift teams during control room operation or by individual apprenticeship in the control room, by focusing on which visual and audible cues, patterns, and rules of thumb that are used during various operation modes, especially during disturbances. Externalization of tacit knowledge can occur if the talk aloud methodology is used during the operation work. Osvalder and Colmsjö [20] state that in this environment eye-tracking could have been an additional useful tool understand on what cues the operators focus their view during operation control.

3 Methodology and Data

The present study was an initial exploratory pre-study. In the first step, a literature review was performed. The literature review was conducted to assess the research field related to MET and to find studies reporting on the use of the eye-tracking methodology. In total 12 databases were searched for peer-reviewed articles. Through this search, 114 documents were selected for further analyzes. In all, 48 articles were identified as relevant. In the second step, data was collected during two cadet pilot courses using observations, interviews, a focus group session including questionnaires, and eye-tracking glasses.

The evaluation of the pilot MET and its procedures were made in order to understand how the MET was performed. Observations and interviews were used during one pilot basic course and one pilot recurrent course, resulting in total of 85 h of observations. In total 25 participants were enrolled on a voluntary basis; 6 pilots, 12 cadets, 5 instructors and 2 administrators/technicians. All participants were employed or probationary employed by the Swedish Maritime Adminstration. The response rate for the interviews was 76%.

During the pilot basic course, eye-tracking glasses were operated by four cadets in three different simulators, in three-member crew teams during one scheduled simulator session (45 min). Each crew consisted of one Master, one observer (for educational purposes) and one cadet acting as a pilot. The cadet wore the eye-tracking glasses. Furthermore, two instructors assessed the eye-tracking equipment (including glasses, monitoring screens and software) before, during and after the scheduled pilot basic as well as recurrent simulator sessions.

Based on the literature review, a questionnaire was designed containing questions on didactics, methodology, issues in general, prerequisites and limitations during the MET, as well as questions on what is consistent with being a skilled pilot. The questionnaire served two purposes: (1) to collect the views from the instructors in a focus group setting on how they conducted their MET, and (2) if eye-tracking methodology could be used as an instructor supporting tool. The focus group consisted of 5 instructors and lasted for 2.5 h. The discussions in the focus group were audio recorded and transcribed. A thematic inductive analysis based on Braun and Clarke [21] was used where topics were examined, categorized and then clustered.

The eye-tracking equipment was also continuously assessed in general terms of operational prerequisites and limitations during the cadet MET course, the recurrent course as well as during other time-periods (in total for 21 h) and included both cadets, pilots and instructors. Data were collected on how the eye-tracking equipment functioned from technical, organizational, physiological and psychological perspectives based on observations and notes from evolving commentaries. The observations were documented on paper, by photography and by screen shots on the monitoring screen. The observations included operational aspects on the eye-tracking equipment: range, limitations on data storage capacity, contingency operations when loss of wireless communications, limitations for wearing normal glasses, reading glasses or contact lenses when using eye-trackers, head posture and gaze techniques, physiological and psychological discomfort when wearing eye-trackers that could affect performance during simulator sessions. Discomfort was gathered in terms of elevated stress levels, the notion of being observed through the eye-trackers as well as discomfort from the physical effects of wearing eye-trackers.

4 Results

The results indicated that all five instructors had challenges when determining where the cadets' visual focus were during basic and recurrent simulator sessions. Furthermore, all instructors stated that the cadets seemed to focus too much inside the ship's bridge, using ECDIS, radio, conning information and the Pilot Portable Unit (PPU). They interacted with the vessel crew at the expense of the outside view. The instructors also reported that they would like objective measurements of the cadets' eye-focus instead of the subjective data. When the cadets used eye-tracking equipment, the instructors reported that their own situational awareness increased, since they could more accurately monitor where the cadets were focusing.

The results also showed that combining simulator-based MET with eye-tracking technology could present opportunities of improvement in terms of didactics and methodology. Both instructors as well as cadets suggested that eye-tracking could be used to assess eye-focus, situational awareness as well as levels of workload and stress. One topic that emerged from the interviews was the belief that it was beneficial using eye-tracking throughout briefings and de-briefings during simulator sessions. Briefings and de-briefings could then be reviewed in groups, in solitude and with or without instructors, in real time or afterwards thus facilitating group learning or guided discoveries. About 50% of the pilots, 67% of the cadets and 67% of the instructors initially reported that their stress level and workload increased and that their situational awareness decreased when wearing eye-trackers. They stated that after spending some time wearing the eye-trackers, these effects weakened.

Eye-tracking equipment was reported to have limitations in terms of range from the master computer station for maintained visual real-time observation. The eye-tracking glasses were reported not suitable for all participants: wearing glasses (normal as well as reading glasses) and contact lenses posed an issue, since incorrect eye-focus data was generated. Participants also reported difficulties maintaining the required head posture and not gazing down below the eye-tracking glasses.

5 Discussion

When striving for visual expertise, the eye-tracking methodology is considered as a useful support-tool. This is a conclusion based on previous research and confirmed in this explorative pre-study. Eye-tracking can be deployed before, during and after sessions, not only to assist the instructor with information on student eye-focus, but also for briefings. However, introducing eye-tracking equipment into existing education and training practices have some implications. These implications include technical aspects of eye-tracking equipment versus simulator installations, requiring changes in the syllabus as well as the pedagogical and didactical transformations that follow, psychological and physiological limitations of participating students, ethical issues as well as interactions with trade unions and other organizations. The pre-study furthermore showed the need for accustoming the participants into wearing eye-trackers before commencing the actual simulator session.

Knowledge in any shape can be viewed as the final form of information, which requires a substantial effort to evolve. Tacit knowledge is difficult to transfer even if methods such as socialization and externalization have been proposed. The transference of tacit knowledge is an ongoing process between the cadet and fellow senior pilots and/or instructors. Eye-tracking methodology could be a means of transferring tacit knowledge, in terms of externalization, and in order to assess and establish new standard operating procedures (SOP:s) for MET. However, in terms of socialization eye-tracking is assessed as minor effective in transferring tacit knowledge. Tacit knowledge is however transferred continuously in terms of socialization to the cadet imbedded in practical pilotage missions and in the social interaction onboard, as well as during social interaction at the pilotage station.

The results from this initial exploratory pre-study can be used as input when preparing for future studies in simulator settings with eye-glasses, including quantifiable success factors such as speed, time, navigational errors and physiological variables for example heartrate and self-assessments on stress, workload and situational awareness.

6 Conclusions

The exploratory pre-study indicated the following aspects:

- Eye-tracking support can be used as a mean of enhancing pilot training in simulator settings
- Eye-trackers can impose limitations on the usage of normal glasses, reading glasses and contact lenses
- Head posture, gaze behavior and wearing eye-tracking equipment in general can have implications on workload, stress levels and situational awareness
- Eye-tracking support can be useful as a didactic tool improving the situational awareness of both instructors and cadets
- Eye-tracking can be beneficial providing means of transferring tacit knowledge from pilot experts to cadets through externalization.

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From Tacit Knowledge to Visual Expertise: Eye-tracking Support in Maritime Education and Training

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The maritime pilot

- An expert with knowledge on specific maritime areas
- Extensive experience as a Captain in general
- Supports the piloted ship's Captain during navigation
- Undergoes education and training in classrooms, vessels, in simulators and on site at pilot stations
- Receives continuous education, training and evaluation over time

Ports Australia 2018

The maritime pilot

- Operates in a complex safety-critical maritime environment, requiring continuously adjusted methodology during education and training
- Competent in technical as well as non-technical areas
- Transfers tacit knowledge to less experienced pilots by socialization and externalization

Swedish Maritime Administration 2020

Eye-tracking

- Can be used to assess eye-focus, dwellings, scan-patterns, and focus areas
- Equipment can be fixed or mobile
- Can provide real time observations and/or post time observations
- Can be analyzed by software and presented in different ways such as films, heat maps, and statistics

Tobii AB 2020

Objective

- Assess how Swedish Maritime Administration pilots conduct education and training of maritime pilots
- Judge eye-tracking methodology as a training-tool
- Assess eye-tracking methodology as a mean of transferring tacit knowledge from expert to novice maritime pilots

Methodology

- Exploratory pre-study
- Literature review
- Observations during simulator sessions with mobile eye-tracking equipment
- Observations during maritime pilot operations
- Interviews
- Questionnaires

Participants

- 6 maritime pilots
- 12 maritime pilot cadets
- 5 maritime pilot instructors
- 2 administrators/technicians

Swedish Maritime Administration 2020

All participants and simulators kindly provided by the Swedish Maritime Administration

Results

- Instructors lacks means of objective measurements of cadet eye-focus
- Eye-tracking can be used to assess eye-focus, situational awareness, workload, and stress
- Situational awareness, for *both* instructors and cadets, increased when using eye-tracking

Results

- Eye-tracking can be used during briefings and de-briefings before, during and after simulator sessions
- Eye-tracking can be used individually and/or in group settings
- Constraints, in terms of physiological and technical issues, is at hand when using eye-tracking equipment

Conclusions

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- Maritime pilot education and training can be improved in terms of pedagogy, didactics, and methodology by using eye-tracking
- Eye-tracking is useful for transferring tacit knowledge in simulator settings, but not during other parts of the education and training
- Head posture, gaze behavior and wearing eye-tracking equipment in general can have implications on workload, stress levels and situational awareness

Please contact me if you have any questions

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RESEARCH REPORT 2

Eye-Tracking in Simulator Training and Assessment: A Semi-Structured Meta-Review

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ABSTRACT

The aim of this meta-review is to chart out a) how eye-tracking is currently used in training and assessment, and b) the barriers and benefits of using eye-tracking reported in the literature. The results show that eye-tracking is used for identifying differences between novices and experts and for capturing expert gaze patterns. Different gaze patterns can be used for gaze training, formative assessment of non-technical skills, as well as summative assessment of technical skills. Further, it is appreciated as an unobtrusive technology that enables a quantitative assessment of objective parameters. Hence, the promise of using eye-tracking for informing instructional design as well as for designing training systems and improve learning environments is clear. However, it is important to consider that implementing eye-tracking is a rather expensive and time-consuming endeavor that requires carefully designed tasks and task analyses to fulfil its potential.

Keywords: Eye-tracking, Simulator training, Simulator assessment, Meta-review

INTRODUCTION

The potential for using eye-tracking as quantitative and objective tools for training and assessment has gained substantial attention across domain with high standards for safety (Rosch & Vogel-Walcutt, 2013). An initial and unstructured search for literature on eye-tracking applications for training and assessment found a large number of reviews that explore the potentials of using eye-tracking technologies in socio-technical working environments (Rosch & Vogel-Walcutt, 2013; Ashraf et al. 2018; Fox & Faulkner-Jones, 2017; Merali et al., 2017; Tien et al. 2014). Given the considerable number of studies conducted on this topic, the aim of this study is to synthesize results from previous reviews on eye-tracking support in training and assessment for work in complex socio-technical domains. In particular, the objective is to map out a) how eye-tracking is used in training and assessment, and b) the barriers and benefits of using eye-tracking reported in the literature, in order to formulate guidelines for implementing eye-tracking in the study of visual expertise in socio-technical environments.

The increasing availability of relatively inexpensive, user-friendly, unobtrusive and non-intrusive eye-tracking technology has resulted in increasing number of eye-tracking studies across scientific disciplines and domains. Improvements in eye-tracking technology (e.g., sampling rate, accuracy, fewer physical restrictions) have enabled researchers to capture previously unavailable data and measures (Klein & Ettinger, 2019). Technological development has enabled both higher sample rates and accuracy which, in turn, enable researchers to capture a more detailed and accurate representation of eye movements. The most frequently reported eye-tracking measures have at least traditionally been fixations and saccades. The term fixation denotes an event in which the eye, or gaze, stops moving for a certain period of time, whereas saccade refers to the rapid eye movements between fixations (Holmqvist et al. 2011). While both stimuli-driven and volitional saccades are often considered as exploration of the visual environment, fixations are hypothesized to be an indicator of attention to a certain position (Klein & Ettinger, 2019; Holmqvist et al. 2011). However, it is debatable to what degree our eye movements and fixations influence, and are influenced by, our cognitive system in various situations. Furthermore, it is somewhat unclear to what extent our eye movements are affected by training and if, and how, eye movement measures are related to cognitive processes, performance or learning outcomes (Mayer, 2010). While these methodological and theoretical issues call for caution in interpretation of eye movement data, they also constitute an exciting research agenda which, in turn, has resulted in a thriving field of research.

This study is designed as a meta-review, that is, a review of previous reviews or meta-analyses (Sarrami-Foroushani et al. 2015), following a semi-structured review approach to be able to synthesize the state of knowledge between disciplines and the variety of methodological contributions across different domains. Semi-structured approaches are suitable for mapping a field of research and synthesize the state of knowledge to set an agenda for future studies (Snyder, 2019). While the approach might take on systematic search strategies, studies often lack the scientific rigor of systematic or scoping reviews. What is considered important also for the semi-structured review method is a transparent and developed research strategy for the audience to determine the worth and value of the chosen topic, method used and findings from the study (Snyder, 2019). In accordance with best practices, the study design is guided by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol for systematic reviews (Moher et al. 2015).

METHOD

The search for literature was conducted in February 2021. Advanced search options for discriminating type of articles (reviews) and timespan (2010-2021) were used on three databases: Scopus, Web of Science and Science Direct. Using search words "eye tracking", "simulator", "training" and "assessment" when searching through article titles, abstracts and keywords, a total of 403 studies were identified (Figure 1).

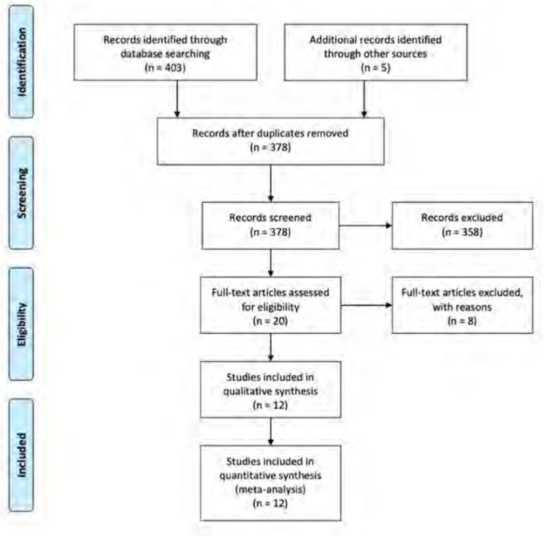

Figure 1: PRISMA 2009 Flow diagram representing the process of identifying, screening, and excluding/including relevant reviews in the meta-review.

Table 1. Studies included in the meta-review.

Authors	Domain	No of studies
Ashraf et al. (2018)	Medicine	33
Castillo-Segura et al. (2021)	Medicine	101
Fox & Faulkner-Jones (2017)	Medicine	61
Garden et al. (2015)	Medicine	8
Hermens et al. (2013)	Medicine	21
Levin et al. (2019)	Medicine	76
Limbu et al. (2018)	Cross-disciplinary	78
Merali et al. (2017)	Medicine	9
Robbins & Chapman (2019)	Transport	13
Rosch & Vogel-Walcutt (2013)	Cross-disciplinary	319
Tien et al. (2014)	Medicine	24
Ziv (2016)	Transport	50

After removing duplicates, 378 studies were screened. In this step, articles that didn't meet the inclusion criteria or lacked an explicit focus on eye-tracking support in simulator training and/or assessment were excluded. In all, 20 full-text articles were assessed for eligibility. After reading full-text, 12 studies remained and are included in the meta-review (Table 1).

RESULTS

The results of the meta-review show how eye-tracking is used for identifying differences between novices and experts and/or capturing expert gaze patterns. Gaze patterns can then be used for gaze training, formative assessment of non-technical skills as well as summative assessment of technical skills. Moreover, the results show how eye-tracking is appreciated as an unobtrusive technology that enables a quantitative assessment of objective parameters. The different uses as well as the barriers and benefits reported in the literature are described in the sections that follows.

Uses of Eye-Tracking for Training and Assessment

For training purposes, expert gaze patterns can be used for gaze training (Ashraf et al. 2018; Hermens et al. 2013). Gaze training in this context originates from laparoscopic surgery training where trainees are taught to adopt the gaze strategies of expert laparoscopic surgeons. While gaze training traditionally has been a matter of detailed, verbal instruction, recent eye-tracking studies has shown that gaze training by adding visual cues to a virtual environment, for example by using augmented reality, is a fruitful approach to teach novices to adopt expert gaze patterns (Tien et al. 2014; Limbu et al. 2015). Moreover, showing expert gaze patterns on a screen during a simulated task can be used for guiding novices to complete the tasks (Tien et al. 2014). Adopting expert gaze patterns have shown to lead to improved performance in terms of more efficient eye and hand movements as well as fewer errors in several medical tasks, including laparoscopy surgery and surgical knot tying (Ashraf et al. 2018; Tien et al. 2014). Hermens et al (2013) put forward the argument that gaze training may be especially effective since eye movements mainly rely on subconscious thought, which in turn are supposed to be less susceptible to the influences of stress. However, it is still largely unknown if the effect of gaze training is persistent over a prolonged period, or if it represents a permanent shift in gaze pattern (Fox & Faulkner-Jones, 2017). Expert gaze patterns can also be used for formative assessment of non-technical skills (Garden et al. 2015). By combining eye-tracking data with video records from the training situation, gaze behavior becomes visible for both instructors and trainees (Ashraf et al. 2018). Providing the means for showing where the participants guided their attention during training, through the combination of eye-tracking data and video recordings from a simulated scenario, opens for reflections on attention, situation awareness and decision-making (Rosch & Vogel-Walcutt, 2013). Hence, the combination of using eye-tracking data with videos from the simulation show potential as a fruitful approach to facilitate post-simulation debriefing.

Eye-tracking is a method for valid, reliable, and objective assessment of proficiency and therefore eye-tracking has gained most attention in summative assessment of technical skills (Rosch & Vogel-Walcutt, 2013; Fox & Faulkner-Jones, 2017; Tien et al. 2014; Levin et al. 2016). Traditionally, summative assessment of technical skills has been done by direct observation and feedback from an expert (Rosch & Vogel-Walcutt, 2013). Over the years, the search for objective measures have led to the development of a variety of rating scales and efforts to standardize the procedures that should be assessed (Rosch & Vogel-Walcutt, 2013). In the quest for reliable, quantitative assessment methods, eye-tracking has been used to establish objective metrics, e.g., path length, dwell time or number of movements as a metric to define surgical skill (Ashraf et al. 2018; Tien et al. 2014). Since experts and novices seem to demonstrate distinct differences in eye behavior during critical stages of task performance, eye-tracking is considered a useful assessment tool in medical areas such as surgery, pathology, and radiology, well suited for identifying skill level of trainees (Ashraf et al. 2018). However, in research on transportation, i.e., in driver behavior and aviation, the usefulness of eye-tracking for skill assessment is less clear (Robbins & Chapman, 2019; Ziv, 2016). In a review on eye-tracking in aviation, Ziv (2016) concluded that there was inconsistency in the differentiation between expert and novice pilots gaze patterns in the reviewed studies. While these inconsistencies could be attributed to methodological differences between studies, Ziv (2016) still conclude that expert pilots have more defined visual scan patterns with more frequent visits to instruments, and shorter dwell times on each instrument than novices. Similarly, gaze patterns between novice and expert drivers varied between included studies in Robbin and Chapmans' review (Robbins & Chapman, 2019). While it was difficult to differentiate between novices and experts in relation to fixation durations, vertical search and number of fixations, the most noticeable result was that novice drivers display a narrower horizontal search compared to experienced drivers (Robbins & Chapman, 2019). Hence, a conclusion that can be made is that albeit eye-tracking for training and assessment is a large and growing field of research, there is still need of studies that explore gaze patterns in settings characterized broad peripheral fields and the need to focus attention on moving targets.

Barriers and Benefits Reported in the Literature

While modern eye-tracking technologies are relatively inexpensive, user-friendly, unobtrusive and non-intrusive, there are still barriers for implementing eye-tracking in training and assessment reported in the literature. Several studies report costs as a barrier (Rosch & Vogel-Walcutt, 2013; Merali et al. 2014; Castillo-Segura et al. 2021), and several studies report challenges in taking them into use, including difficulties in selecting suitable tasks and/or uncertainty of how to measure specific skills (Fox & Faulkner-Jones, 2017; Merali et al. 2017; Hermens et al. 2013; Limbu et al. 2018). Barriers related to difficulty in programming the equipment are also reported (Rosch & Vogel-Walcutt, 2013). Moreover, studies report that eye-tracking is a rather time-consuming method, generating large data sets that need to be properly analyzed (Merali et al. 2017; Castillo-Segura et al. 2021). Hence, using eye-tracking technologies in training and assessment is still not an off-the-shelf pedagogical method, easily available for the everyday educational practices in complex socio-technical domains. However, there is still a number of benefits associated with using eye-tracking technology for training and assessment that encourage the field to continue studying its worth. As already mentioned, eye-tracking technologies can enable quantitative assessment of objective parameters (Ashraf et al. 2018; Tien et al. 2014; Hermens et al. 2013; Levin et al. 2019) and has shown valuable for training purposes (Merali et al. 2017; Tien et al 2014; Limbu et al. 2018; Robbins & Chapman, 2019). Modern eye-tracking devices are unobtrusive and enable users' natural movement, an important aspect when training or assessing manual skills (Castillo-Segura et al. 2021).

DISCUSSION

As outlined above, the current state of research clearly identifies the potential of using eye-tracking as a tool to support training and assessment across domains. However, there is the need to acknowledge some of the limitations that have been identified in the literature included in this review.

Due to the fact that eye-tracking studies are conducted in controlled environments where instrumentation may set limits to the design of tasks, internal and external validity have been reported to be rather low, such in the studies included in Garden et al. (2015). This is also in line with Robbins and Chapman (2016) who discuss that identified differences in visual search patterns between novices and experts may have been identified due to the fact that comparisons are partially made to extremely experienced drivers (e.g., policemen). This may limit the generalizability of the studies towards the differences between experienced and novice drivers. Further, as noted by Levin et al. (2019) and Robbins and Chapman (2016), there is a limited generalizability of the results across due to the sampling methods in many studies. Sample sizes are reported to be small and the recruitment of subjects, for example using students, may also impact on the potential to generalize from sample to the general public. Moreover, task design and especially the use of eye-tracking to measure cognitive load are mentioned as critical across the reviewed articles. To obtain information on cognitive load during tasks, the study design needs to be built on detailed task analyses and needs to take into concern that certain professions require spatial movements (Rosch & Vogel-Walcutt, 2013) or use peripheral vision (Merali et al. 2017), which both can be problematic to capture in eye-tracking studies. Further, due to the focus on the individual gaze patterns, collaborative tasks and team work remains unexplored (Ziv, 2016). Similarly, Hermens et al. (2013) notes that there is not yet a clear understanding of what characterizes best pattern in terms of skills, which then also may also be impacted by the choice of task under study. In addition, despite the increasing body of knowledge, there is still a limitation with eye-tracking being used to measure cognitive abilities according to Levin et al. (2019) as studies usually lack comparisons to other secondary measurements or psychophysiological responses approaches (Rosch & Vogel-Walcutt, 2013).

This study used a semi-structured review approach based on the PRISMA-protocol. While the initial set consisted of 378 studies, only 12 articles met the inclusion criteria. The included studies do not only show the wide variety of eye-tracking applications across domains, but also exemplify the heterogeneity with which reviews can be conducted. The time spam of included studies differed widely, as did the degree of structure with which the reviews were conducted. Furthermore, it is noted that the number of scientists and experts in this field of research is limited, which means that some research collaborations and clusters may have been overrepresented in the included review articles, in turn affected the obtained results from the systematic analysis.

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Eye-tracking in simulator training and assessment: A semi-structured meta-review

CHARLOTT SELLBERG, GESA PRAETORIUS & MARKUS NIVALA

Research aim, questions and objective

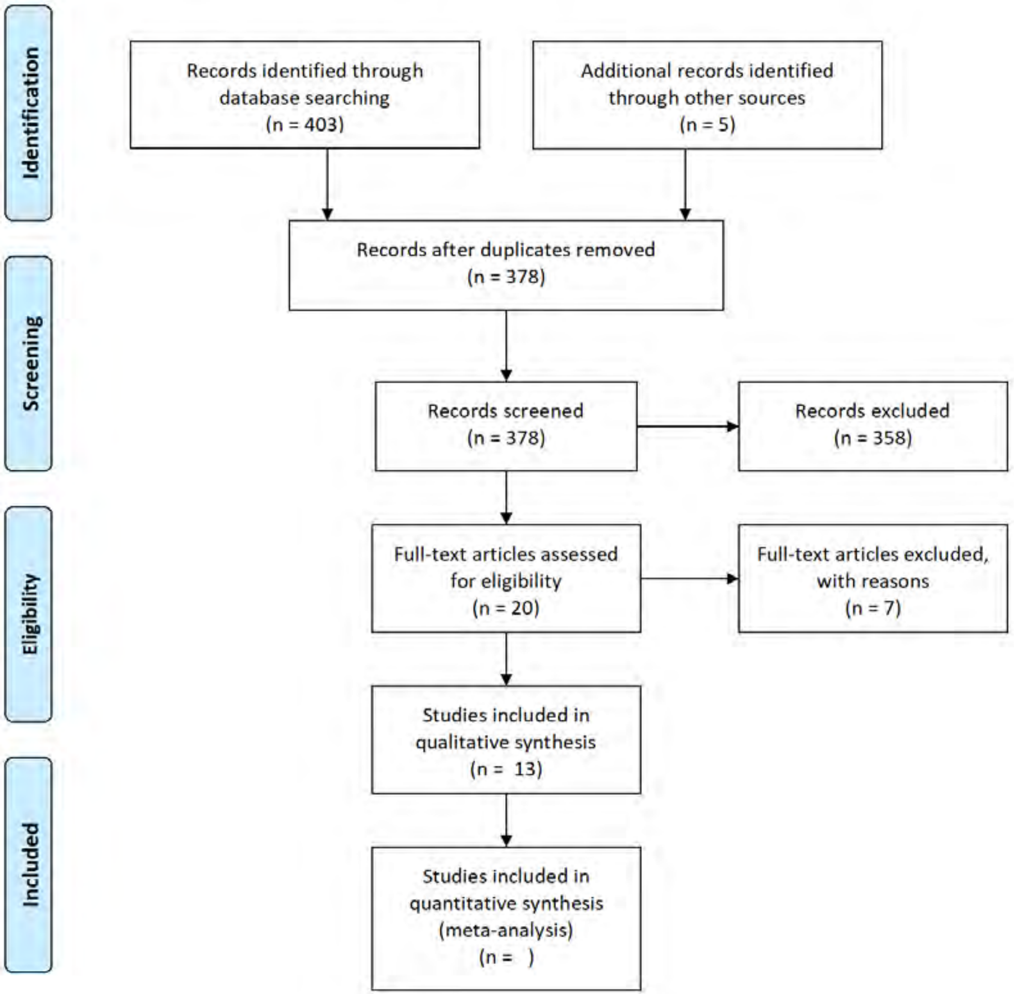
- The aim is to synthesize results from previous reviews on eye-tracking support in training and assessment for work in complex socio-technical domains
- Research questions
  a) how is eye-tracking put to use in training and assessment
  b) what are the barriers for, and benefits of, using eye-tracking
- The objective is to formulate guidelines for implementing eye-tracking in the study of visual expertise in socio-technical environments

Method

- Meta-review, i.e., a review of reviews
- Semi-structured review approach
- Guided by the PRISMA-protocol

Search strategies

- Search in February 2021
- Three databases
  - Scopus, Web of Science and Science Direct
  - Article titles, abstracts and keywords
  - 2021-2021
- Search string
  - “eye tracking” “simulator” “training” “assessment”



Identification
Screening
Eligibility
Included
Records identified through database searching (n = 403)
Additional records identified through other sources (n = 5)
Records after duplicates removed (n = 378)
Records screened (n = 378)
Records excluded (n = 358)
Full-text articles assessed for eligibility (n = 20)
Full-text articles excluded, with reasons (n = 7)
Studies included in qualitative synthesis (n = 13)
Studies included in quantitative synthesis (meta-analysis) (n =)

Purpose of using eye-tracking

- Summative assessment of technical skills
- Formative assessment of non-technical skills
- Identifying differences between novices and experts
- Capturing expert gaze patters

Identified benefits

- Unobtrusive technology
- Enable a quantitative assessment of objective parameters
- Captures differences between novices and experts
- Usable for informing instructional design
- Usable for designing training systems and improve learning environments

Identified barriers

- Expensive
- Time consuming
- Not suitable for all users
- Low robustness
- Difficult to program for different purposes
- Limitations in measurement of peripheral vision
- Unsuitable for tracking open visual fields
- Problematic to use when participants move
- Challenging to select appropriate tasks
- Limitations in measurements of cognitive abilities/specific skills

State-of-the-art

- Low internal and external validity of studies included in the corpus of reviews
  - Small sample sizes
  - Non-representative samples
  - Few intervention studies
- As a result there is still weak evidence for eye-tracking as a tool for training and assessment

How to avoid pitfalls in our project

- Abandon the idea of a (pure) quantitative study/experiment
- Use additional quantitative/qualitative data
- Compare/relate very simple quantitative eye movement measures to additional data
  - Video/audio recording, stimulated recall, ship position & speed etc.?

- Environment and eye-tracking equipment?
- Local (i.e. Port of Gothenburg) or global differences?

RESEARCH REPORT 3

Transferring Tacit Knowledge During Maritime Pilot Training: Assessment of Methods in Use

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Transferring Tacit Knowledge During Maritime Pilot Training: Assessment of Methods in Use

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ABSTRACT

Accurate knowledge management is vital for an organization to perform well. Managing explicit knowledge is relatively easy but managing tacit (implicit) knowledge is not. Effective transfer of tacit knowledge from experts to novices in an organization is therefore essential. Maritime pilotage is a safety-critical operation in which pilots use their expertise to guide vessels in specific waters. The purpose of this study is to improve the Pilot Training Programme (PTP) run by the Swedish Maritime Administration (SMA). The aim of this study is to evaluate and describe the prevailing methods of transferring tacit knowledge during the PTP. This study includes 20 maritime pilots and covers a complete PTP. A qualitative mixed-methods approach was used, based on activity theory and including observations, interviews, questionnaires, and document analyses. The results showed that tacit knowledge transfer during the PTP occurs during situated learning, such as apprenticeships, hands-on learning and communities of work. However, the transfer methods are not sufficiently documented from a didactic perspective.

Keywords: Tacit knowledge, Maritime education and training, Maritime pilot

INTRODUCTION

Accurate knowledge management is vital if an organization is to improve its performance (Nonaka and Takeuchi, 1995), stay competitive (Teece, 1998) and assure productivity (Haldin-Herrgard, 2000). Knowledge management includes the creation, retention and transfer of knowledge (Argote, 2021). However, transferring knowledge in an organization is a complex task. Even if members of the organization are willing to share knowledge, they may be unable to do so (Polanyi, 1966). A substantial amount of knowledge in an organization is hidden and dispersed among its members (Lee, 2000). Members move in and out of the organization due to such things as termination of employment, new recruitment, organizational change or retirement. Thus, there is a genuine risk of knowledge disappearing when people depart (Smith, 2001); the result being a depleted organization. Explicit knowledge may be located, managed and shared with relatively ease (Moreland and Myaskovsky, 2000). This is because it can be coded, documented, stored and transferred (Polanyi, 1958). Literature, instructions, standard operating procedures and manuals are all ways of transferring explicit knowledge (Hyttinen and Rintala, 2005). Implicit knowledge, or tacit knowledge (Kirsner et al. 1998), is not immediately available for conscious retrieval. Tacit knowledge evolves over long periods and is not easily accessible for articulation in speech or writing (Polanyi, 1966). It may be found on both the individual and organizational levels (Nonaka and Takeuchi, 1995). Tacit knowledge may be expressed as skills (Nelson and Winter, 1982), as know-how (Kogut and Zander, 1992) or as procedural knowledge (Stanley and Williamson, 2001). Studies of tacit knowledge have been conducted in organizational settings (Jasimuddin et al. 2005), healthcare (Ambrosini and Bowman, 2001) and security operations centers (Cho et al. 2020). Tacit knowledge has been conceptualized differently depending on the domain (Kothari et al. 2012). However, tacit knowledge transfer largely requires personal interaction and proximity to other individuals, as seen in mentoring, apprenticeships, job rotations or communities of practice (Lave and Wenger, 1991). The tacit knowledge of experienced operators is especially crucial to the safe and efficient operation of safety-critical organizations. Maritime pilotage is a safety-critical operation and a crucial part of the maritime industry in assuring safe, economic and sustainable naval operations (SMA, 2022). Based on extensive local as well as tacit knowledge, maritime pilots (hereinafter referred to as "pilots") provide navigational guidance to mariners on specific waterways, such as harbors, river mouths, canals and on the open sea. Pilots interact with the crew of the piloted vessel, providing advisory information as to navigation and specific properties of the water (depth, obstacles, tides, infrastructure and so on). They also assist during tugging, birthing and mooring operations (SMA, 2022). The SMA assures maritime pilotage in Swedish territorial waters and employs about 200 pilots, who conduct some 33,000 missions annually. The SMA is responsible for the pilot training in Sweden, in which experienced mariners from the shipping industry can enroll, following application, evaluation and selection.

PURPOSE AND AIM

The purpose of this study was to identify ways to improve the PTP to mitigate increasing requirements for safe, economical and environmentally sustainable shipping in Swedish territorial waters. The study aimed to: (1) locate, catch, crystallize, document and describe prevailing methods of tacit knowledge transfer during different elements in the PTP; and (2) provide suggestions on improving the transfer of tacit knowledge.

METHOD

Theoretical Framework

Activity theory (Leontiev 1978, 1981; Vygotsky and Cole, 1978) is a conceptual framework in which activity is the prime unit of analysis. Activity theory is distinguished by collective learning (Kaptelinin, 2005). The human mind evolves by interaction with the environment in which human activities take place; social settings modulated by cultural and social influences

(Kaptelinin and Uden, 2013). Activity systems analysis seeks to systematically extract data (Yamagata-Lynch, 2010) and analyse development within social activities (Sannino et al. 2009), most often in socio-technical systems (Engeström, 1987). Activity systems analysis has been used for research into learning (Scanlon and Issroff, 2005), design (Hjort af Ornäs, 2010) and information systems (Kaptelinin and Nardi, 2006). An activity system is divided into six components of analysis (Engeström 1987, 2000). In such a system the *object* is the activity, the *subject* is the individual(s) being studied, the *tool* is the mediating device providing the means for the activity to be conducted, the *rules* comprise formal/informal rules affecting how the activities take place, the *community* is the social group with which the subject interacts during the activities and the *division of labour* governs the distribution and organization of work in the community. The outcome of the activity system is the result of transforming the object into the outcome (Engeström, 1999). According to Kaptelinin and Nardi, (2006), activities may be further analysed at various levels of abstraction, with activity, action and operation thereby showing different hierarchal levels of activity. Activities are driven by the motivation of the subject; actions are driven by a set of goals and operations are driven by a set of conditions. Furthermore, activities may be conducted based on multiple motives (Kaptelinin and Nardi, 2006). Activity theory has been deployed in organizational studies. However, some researchers claim that it is poorly understood and, indeed, too specialized for that field (Thompson, 2004). Nardi (1996) described activity theory as a powerful tool rather than a theory for making predictions. However, Blackler and Reagan (2009) stated that activity theory is relevant to organizational studies since it gravitates toward studying the dynamic relationships and subsequent friction between individuals, collectivities, objects and language.

The Pilot Training Programme

The PTP lasts about a year and comprises three parts: (1) an introductory course (INTRO) lasting 1-3 months and covering employment conditions, safety, regulations, the SMA organization and general pilotage procedures; (2) a Swedish basic training for maritime pilots course (BASIC) lasting six weeks and comprising maneuvering, navigation, marine resource management (MRM), governmental officer duties, boarding operations, hoisting and hypothermia. The training is held in classrooms, in a simulator environment and in the actual maritime environment. The INTRO and BASIC parts may overlap; and (3) a local training plan (LTP) for 6-12 months depending on location, in which maritime pilot students (hereinafter referred to as "students") acquire knowledge by participating in 50 actual pilotage missions, supervised by a certified pilot. During the PTP, the development of knowledge is strongly characterised by learning in social settings, as with an apprenticeship. The PTP concludes with an examination after which a pilot certificate and pilot license (level 1) are issued. The pilot license regulates the category of vessels for which the pilot is approved. Ultimately, the goal is to gain enough experience to obtain the highest-level pilot license (levels 4-5), permitting unrestricted pilotage. Every third year, re-training is conducted in different focus areas. Simulator training and MRM are used to provide this. The SMA also conducts such continuous training as open-sea pilotage (red card), transitions to other SMA vessels (such as ice-breakers) and evaluations of new routes and procedures.

Study Design

Activity theory was used to evaluate the PPT as an activity system. This entailed a qualitative, mixed-methods study approach comprising observations, interviews, questionnaires and document analysis (for triangulation).

Data Collection

Data collection was conducted intermittently during two different PTP courses in 2020 and 2021. A total of 21 participants were included in the study, consisting of eight students, seven less experienced but licensed pilots, five licensed, experienced master pilots (also serving as instructors) and one administrator who also served as an SMA coordinator for the present study. The mean age was 46, with a standard deviation of eight years. All participants were males, operating out of seven different pilot stations in Sweden. All stations differed in terms of waters, infrastructure and piloted tonnage. A total of 119 hours of observation were conducted and documented over 13 training days. These observations were made during classroom and simulator training at the central SMA training facility in Gothenburg, at pilot stations and during actual missions entering or exiting a major international harbor. No observations were made at the scale ship-handling training facility. Interviews were held individually with all participants, ranging in length from 45 to 60 minutes. A six-point Likert scale questionnaire was also distributed to the participants. This contained background questions, plus questions on knowledge transfer during the PTP.

Data Analysis

The observations took the form of passive participant observations (DeWalt et al. 2010). Field notes (Bogdan and Biklen, 2003) were collected using an observation protocol. Semi-structured interviews (Edwards and Holland, 2013) based on a specified interview guide, were adapted from the eight-step model (Mwanza, 2002b). Interviews were recorded, transcribed and assessed using a thematic (reflective) inductive analysis (Clarke, 2006) and then coded and organized into themes. An even scale was selected so as to exclude a neutral center option (Allen and Seaman, 2007).

Document analyses (Bowen, 2009) were used to provide background and context, identify additional questions, provide supplementary data, track evolution and verify findings (triangulation). The document analyses included assessments of training curriculums, course literature, operating procedure descriptions, intranet databases, printed and electronic documents, illustrations and films. A thematic (reflective) inductive analysis (Clarke, 2006) was used to code and organize the data into themes. Relevant documents were also discussed with the PTP administrative personnel and with PTP instructors. Emerging data was thematized and compared to

Mwanza's (2002b) eight step-model for interpreting an activity system. The eight step-model conceptualized data from the study into components of the activity system model proposed by Engeström (1987, 2001).

RESULTS

The PTP was analysed as an activity system (Figure 1), aided by observations, interviews, questionnaires and document analyses. The PTP was analysed on the activity level where the *outcome* was the examination/certification of new pilots to adhere to set SMA requirements. The *motives* had two dimensions: the SMA motive to provide suitable training and the students' motive to progress towards a new profession. The *object* of the PTP is to reproduce pilot-specific skills, using theoretical, non-situated learning in classroom settings combined with situated learning in apprenticeship settings.

The *subjects* have different roles during the PTP. Students are exposed to knowledge in various ways at various times and at various locations such as pilot stations, pilot vessels, piloted vessels, scale ship-handling facilities, simulators, classrooms and self-studies on or off-site (Table 1). Informal interactions, such as during meals and coffee breaks, during walks, or during free-time activities were important knowledge transfer nodes. These nodes were also important for transferring tacit knowledge, among other things by telling stories from the domain and thus verbalizing tacit knowledge at some level. Instructors provided teaching according to a set syllabus. However, this syllabus did not sufficiently describe (in terms of didactics) how the PTP was to be implemented. *Tools* were predominantly: (1) the ship-bridge simulator, (2) the actual pilot missions during the LTP and (3) creation of the navigation booklet. All three serve as important vehicles for transferring tacit knowledge. Students prepared, performed, evaluated and discussed ship-bridge simulator sessions in an open (non-punitive) environment, interacting with each other and with their instructors. This afforded a foundation for discussions and animations from completed sessions and created a collective learning environment.

Briefings and de-briefings connected to these sessions provided students with (tacit) knowledge emanating from their instructors. This took the form of heuristics, such as golden rules, guidelines, applied experience and know-how. Non-situated theoretical learning, such as ship handling, navigation and stability is provided during the PTP to some degree but is mostly expected to have already been acquired. Students are already experts in their profession as mariners and the PTP may be viewed as a new dimension of that profession. Comprehensive course literature could be a way to review old knowledge and introduce new knowledge in a more organized manner. During the LTP, the students entered a state of apprenticeship. Embedded in actual pilot missions, students progressed towards their new profession in a community of practice. Interacting with their supervisors, students developed trade-specific hands-on knowledge. The LTP exposed students to a substantial amount of tacit knowledge which, in turn, is crystalized in the navigational booklet. This booklet has dual functions: 1) it crystalizes knowledge for the student,

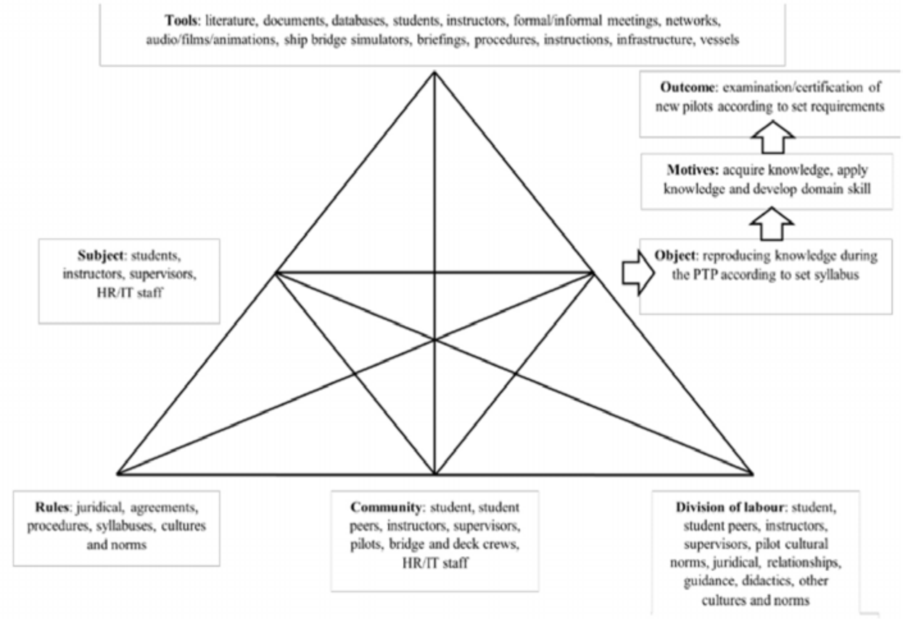

Figure 1: The pilot training program as an activity system. Adapted from Engestrom (2000).

Table 1. Compilation of tacit knowledge transfer locations in the PTP based on observations, interviews, questionnaires and document analyses.

	Course literature	Juridical	Databases	ICT	Film	Audio	Ship bridge simulator	LTP booklet	Formal meetings	Informal meetings	Written instructions	Verbal instructions	Briefings	Observations	Reflections in group	Peer students	Hands-on	Communities of practice
INTRO	•	••	•	•	-	-	-	-	•	•	••	••	-	••	•	•	•	•
BASIC	••	••	•	•	••	•	•••	••	•	••	••	•••	•••	•••	••	•••	•••	••
LTP	•	••	•	•	-	•	•	•••	••	•••	•	•••	•••	•••	•	-	•••	•••

- None • Minor •• Medium ••• Major.

acting as a didactic tool; and 2) it creates knowledge and acts as a personal knowledge basis for future pilot missions.

The use of tacit knowledge transfer tools during the PTP showed a low level of documentation in terms of didactics. *Rules* consisted of nautical regulations, procedures, syllabuses, group briefings/de-briefings solely in cultural settings. These rules play an important role in facilitating tacit knowledge transfer during the PTP. *Division of labour* in terms of students, student peers, instructors and the didactic prerequisites enabled the transfer of tacit knowledge. However, consistent with the other elements of the activity system, this interaction was insufficiently documented.

DISCUSSION

We often know more than we can tell or explain to others. Some knowledge is so deeply embedded that we do not think about what we know and what we are doing – we just do it. This is tacit knowledge, expertise, or know-how and will have taken many years to achieve. The results of this study provide insight into how, where and when tacit knowledge is transferred during the PTP run by the Swedish Maritime Administration. Much of the knowledge transfer happens during situated learning environments and is not sufficiently documented, either in didactic terms or content. Much of the didactic management is therefore located at individual instructor level, resulting in personal knowledge transfer strategies. A standardised syllabus including specified didactics could help students prepare for their next training session and identify the level of knowledge required after it. Activity theory may be assessed at different hierarchical levels. The PTP was assessed at *activity* level as a motive-directed system. At the lower action level, goals direct actions and at the lowest operational level, conditions direct them. Actions carried out via operations may be seen as being executed without full attention to its execution. Such actions resemble the actions of procedural nature, skill and know-how; all of which are tacit-knowledge-based actions. This is consistent with observations during the PTP in which instructors provide know-how, heuristics, or guidelines in tactical terms. The capability to raise actions from an operational level to a conscious level is useful when assessing tacit knowledge transfer. Further assessing the PTP on an operational level can feed data into the suggested standardised syllabus. Developments causing drainage of knowledge in an organization, such as staff movements, may be unexpectedly beneficial for another (receiving) organization. Job rotation, in which experienced, non-instructor pilots act as mentors during designated parts of the PTP, could present a way to increase the transfer of tacit knowledge. An alumni function, with former students returning to the PTP as instructors/supervisors might be another way to feed applied experience into the PTP. The PTP has several elements, not all of which could be assessed using the methods in the study. Thus, the study had to rely on triangulation to mitigate this problem. Other shortcomings were that the number of observed pilot LTP missions had to be reduced due to Covid restrictions, the scale-model ship handling part could not be observed at all and the activities at the SMA training facility had to be observed over an extended and fragmented time.

CONCLUSION

The PTP is largely dependent on situated learning such as community of practice, apprenticeship, or hands-on training. Learning is therefore mainly located in the relationship between learning and the social situation in the specific environment of that learning. Didactic methods for transferring tacit knowledge are furthermore located at individual instructor or supervisor level and are not sufficiently documented in didactic terms.

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Transferring Tacit knowledge During Maritime Pilot Training: Assessment of Methods in Use

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The maritime pilot

- An expert with knowledge on specific maritime areas
- Extensive experience as a Captain in general
- Supports the piloted ship's Captain during navigation
- Undergoes education and training in classrooms, vessels, in simulators and on site at pilot stations
- Receives continuous education, training and evaluation over time

Ports Australia 2018

The maritime pilot

- Operates in a complex safety-critical maritime environment, requiring continuously adjusted methodology during education and training
- Competent in technical as well as non-technical areas

Swedish Maritime Administration 2020

Tacit knowledge

- Accurate knowledge management is vital if an organization is to improve its performance, stay competitive and assure productivity
- A substantial amount of knowledge in an organization is hidden and dispersed among its members
- Transferring knowledge in an organization is a complex task
- Implicit (tacit) knowledge is not immediately available for conscious retrieval and can be difficult to articulate or express in text
- Tacit knowledge may be expressed as skills, as know-how or as procedural knowledge
- Tacit knowledge of experienced operators is especially crucial to the safe and efficient operation of safety-critical organizations

The Swedish Pilot Training Programme

- Provided by the Swedish Maritime Administration
- Duration is approximately one year
- All participants are experienced captains
- Contains three parts: introduction (1-3 months), basic training (6 weeks) and local training (6-12 months)
- Class-room, simulators, training missions, other hands-on training
- Concludes with a pilot certificate and a license

Purpose & Aim

- Purpose: to identify ways to improve the Swedish Pilot Training Programme (PTP) to mitigate increasing requirements for safe, economical and environmentally sustainable shipping in Swedish territorial waters.
- Aim: (1) locate, catch, crystallize, document and describe prevailing methods of tacit knowledge transfer during different elements in the PTP; and (2) provide suggestions on improving the transfer of tacit knowledge.

Methodology

- Activity theory was used to evaluate the PTP as an activity system
- Qualitative, mixed-methods study approach

Data Collection

- Data collection during two PTP courses during 119 hours during 13 training days
- 12 maritime pilots, 8 maritime pilot cadets, 5 maritime pilot instructors, 2 administrators/technicians
- Activity theory framework
- Observations, interviews, questionnaires and document analysis
- Access to pilot stations, vessels, training facilities as well as to participants kindly provided by the Swedish Maritime Administration

Swedish Maritime Administration 2020

Results

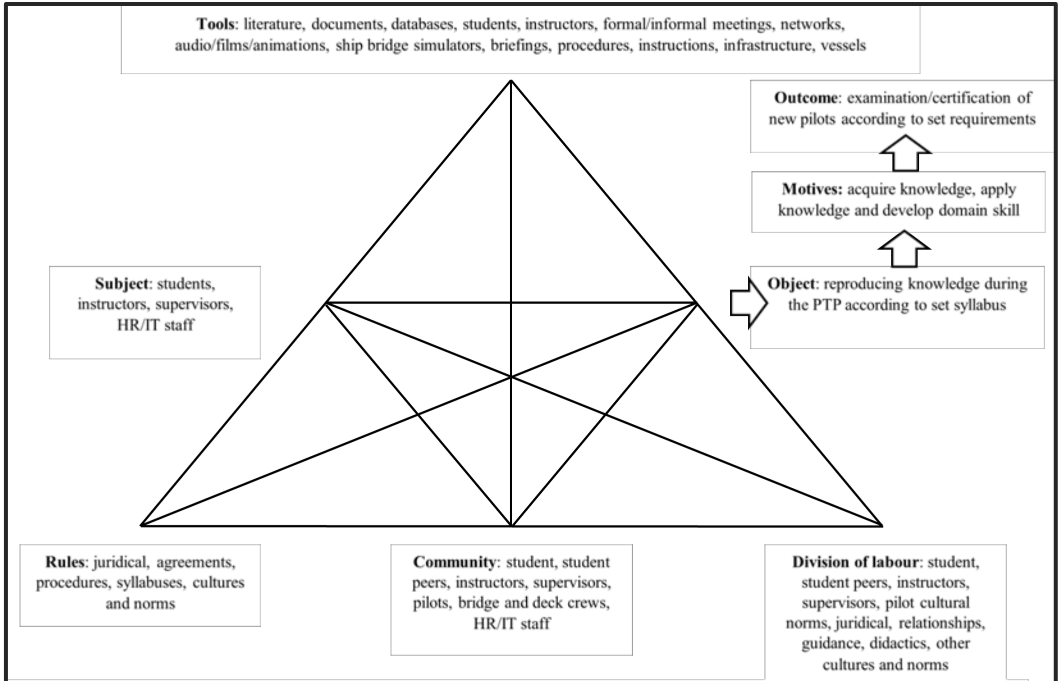

Figure 1. The Pilot Training Program as an activity system. Adapted from Engeström (2000).

Results

- The PTP is largely dependent on situated learning such as community of practice, apprenticeship, or hands-on training
- Learning is mainly located in the relationship between learning and the social situation in the specific environment of that learning
- Didactic methods for transferring tacit knowledge are furthermore located at individual instructor or supervisor level and are not sufficiently documented in didactic terms

Results

- Eye-tracking can be used during briefings and de-briefings before, during and after simulator sessions
- Eye-tracking can be used individually and/or in group settings
- Constraints, in terms of physiological and technical issues, is at hand when using eye-tracking equipment

Conclusions

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The Pilot Training Programme (PTP) can be improved by better managing tacit knowledge management using:

- Improved and relevant course literature
- An alumni function, where recently trained pilots return to the PTP to share their experience from the training with the current classes
- Experienced pilots rotating back to the PTP as instructors to consciously feed applied knowledge from the domain into the PTP
- Standardizing syllabuses including expanded sections to help students stay ahead
- Continuously documenting where, how and when tacit knowledge is transferred

Please contact me if you have any questions

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AVANCEZ

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RESEARCH REPORT 4

Exploring Strengths and Weaknesses in Professional Marine Pilot Education

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Exploring Strengths and Weaknesses in Professional Marine Pilot Education

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ABSTRACT

This article presents findings from a Strengths, Weaknesses, Opportunities and Threats (SWOT)-analysis of the current marine pilot training. Five experts participated in a focused group interview. The results show that the training is strengthened by the wide variety of practical experiences that the instructors gain from actively working as pilots while being engaged in the education. Furthermore, the advantage of being able to use real-life experience to design training units increases the transferability of training to work settings. However, the experts also highlight the general lack of organizational support and pedagogical training, which may affect the quality and delivery of the education, as well as the lack of short- and long-term evaluation, so it remains unknown what parts of the education are successful and where potential improvements are necessary. The paper concludes by arguing that maritime pilot training should be developed into a professionalized teaching practice.

Keywords: SWOT-analysis, Maritime education and training (MET), Maritime safety

INTRODUCTION

In 2020, the global merchant fleet encompassed 98715 vessels with a carrying capacity of 2.1 billion dwt (UNCTAD, 2020). Thus, maritime transport can be considered as one of the major transport modes and the backbone of the globalized economy. Shipping can furthermore be regarded as a high-risk industry (Perrow, 1999) with a potential to cause negative consequences not only to those serving onboard, but also to the marine environment and the general public in case of an incident or accident. To ensure safety in operations, training and education are considered as one of the foremost means to equip mariners with essential skills and necessary tools (Praetorius, Hult and Österman, 2020). Other means include governmentally introduced safety measure, such as Vessel Traffic Services (VTS) or pilotage.

A particularly safety-critical part of a ship's voyage is the port approach. Port approaches normally pose high demands on the skills of ship-handlers due to the traffic density, limited navigational space and local circumstances that need to be taken into concern in to enable a safe voyage into port (National Research Council, 1994). Thus, many port approaches and other sensitive sea areas require vessels to make use of marine pilotage to ensure safe passage.

Marine pilotage is one of the foremost measures to increase maritime safety and decrease the risk for hazards in areas that are challenging to navigate in. Pilotage is usually carried out by marine pilots, who are mariners with local expertise that support and consult a vessel's master in navigational matters. Their work enables an effective communication with local and shore-based service, thus promoting a safe passage (Darbra *et al.*, 2007). As pilots play a crucial role in ensuring maritime safety and protecting the environment, training and education play a particularly important role.

This study presents findings from a focused group interview that was conducted with five experienced pilots, who also work as instructors within the marine pilot education. The aim of the interview was to explore strengths and weaknesses in today's education, as well as to identify potential opportunities and threats for the current training regime. Furthermore, the focus group also intended to highlight potential future directions for improvements of the professional education and training, especially with regards to novel technology.

SWOT-ANALYSIS AS ANALYTICAL TOOL

The so-called SWOT-analysis is a strategic planning tool developed in the late 1960s to explore how to achieve a good fit between external or contextual factors (threats and opportunities), and internal characteristics of an organization or business (strengths and weaknesses) (Hill and Westbrook, 1997). The aim of a SWOT is to provide support in complex decision-making processes by ordering and reducing the amount of information available to guide the decision makers (Arslan and Turan, 2009). The first publications using SWOT-analyses appear to stem from the 1960s, but the origin itself remains unknown according to (Helms and Nixon, 2010)

While traditionally utilized for strategic management decision and policy development, within recent years the analytical tool has been applied to wide variety of domains and problem spaces. Examples for applications in the maritime domain are the enhancement of safety analyses and risk reducing measures for marine casualties in the Istanbul Straight through combining SWOT with an Analytical Hierarchy Process (AHP) method (Arslan and Turan, 2009), suggested improvements to institutional efficiency in maritime higher education based on questionnaire data analyzed with the help of the tool (Paraggua, Mobo, Ronalyn C. Acuavera, Villavicencio and Pasa, 2022), and the use of SWOT to identify what constitutes successful bridge team organization (Arslan and Er, 2008).

Within the area of education and training, several studies report the usefulness of SWOT when exploring potential training needs and education program developments. Longhurst et al. (2020) used a SWOT to analyze how higher education institutes adapted their anatomical education as response to the ongoing pandemic. The analysis enabled highlighting of similarities and differences in how universities changed their training delivery and teaching modality to meet the constraints imposed by the pandemic crisis. They found that the tool was useful to initiate discussions and strategy development of curricula and assessment methods. Another example for an educational application of a SWOT has been presented by Engelbrecht, Lindeman and Hoermann (2019) who discuss the application of VR technology in the training of professional firefighters. They found that VR is cost-effective and allows the training of challenging events in a safe environment, as well as lessons learned in other high-risk domains may be easier transferred to the firefighting domain. However, in terms of weaknesses and threats, limited knowledge about the applicability of VR technology for team training, as well as the uncertainty of skill transfer and potential skill decay were identified by the researchers.

The usefulness of the SWOT-analysis to improve training evaluation has been discussed by Wankhede et al. (2021) who propose a self-evaluation matrix for trainees and mentors within the Indian surgical training. Their adopted approach can both be used to identify gaps and deficiencies within the current training regime, as well as it can help to foster discussions between mentors and trainees through highlighting trainee perceptions. They also found that SWOT as tool for self-evaluation actively promotes the development of strategies to seize potential opportunities within the training.

METHODOLOGY

To explore current strengths, weaknesses, threats and opportunities within the marine pilot education program, a SWOT-analysis was conducted with five experienced pilots in a focus group interview. The SWOT was conducted as part of a focused group interview (Patton, 2014) and aimed to provide a structure for the discussions.

Participants

Five professional pilots involved in the current pilot education participated in the focus group. All respondents are holders of an unlimited master license and have previously served in the merchant fleet before becoming marine pilots. The years of working experience in the merchant fleet ranged from 8 to 15 years, and experience as marine pilot from 13 to 23 years. Further, the respondents represent different pilotage areas along the Swedish coast. In addition to working as pilots, all the respondents are engaged in the professional education for marine pilots as instructors. Their area of expertise included among others simulator-based training, maritime resource management, and on-the-job training of both pilot trainees and experienced pilots. Due to the limited number of subject matter experts within this domain, further information about the participants will not be disclosed to ensure confidentiality.

Procedure

Prior to the interview, all respondents had received an information sheet about the project, the focus group's aim and how participant data would be handled. They had also been asked to provide demographic information (age, educational background, years as pilot etc.) and submit a signed consent form ahead of the scheduled interview.

The SWOT was conducted as a focus group interview via a digital meeting software due to the ongoing pandemic and lasted approximately 3 hours. A web-based tool to facilitate cooperative working and knowledge sharing was used to support the SWOT-analysis and provided a digital whiteboard where participants could choose to fill in and categorize digital post it-notes during the focus group.

The focus group started by a short introduction to the project and the aim of the scheduled discussion. The web-based tool was introduced as means to facilitate collaboration during the interview and a link to the online whiteboard was provided to the participants. After the participants had been given the chance to ask questions, the interview and recording started.

Each of the four aspects of the SWOT was discussed separately, but the procedure remained the same throughout the whole focus group. The order of the discussion was that first strengths, then weaknesses, opportunities and last threats were discussed. Each of the discussions took approximately 30 to 40 minutes and started by the participants having 10 minutes to note down all aspects they perceived in relation to the aspect under discussion. Each aspect was noted on a digital post it-note and the online whiteboard enabled the participants to see each other's notes. After 10 minutes, the two moderators took 5 minutes to sort all the notes and then started a moderated discussion by explaining which groups of aspects had emerged. In the discussion the participants were encouraged to provide details on the identified aspect, give examples and explain their reasoning. The recordings of the focus group were transcribed verbatim to facilitate the analysis.

RESULTS

The following paragraphs will present a summary of the strengths, weaknesses, opportunities and threats identified by the experts.

Strengths

The experts highlight that the current pilot education shows a good balance between theory and practice. This is achieved by varying the training context and modality. Classroom-based teaching is combined with simulator training and complements the more traditional on-the-job training onboard. It is also emphasized that the instructors have open dialogue with each other, which helps to make use of the wide experiences and expertise among trainers and trainees. Furthermore, being an instructor and active pilot at the same time enables the experts to keep training units up-to-date and student-centered, which may also increase the overall transferability of training content to the work settings.

Weaknesses

In the current pilot education, an emphasis is put on instructors being active pilots at the same time as they train professionals. While this is an advantage with regards to the training content, the experts expressed that they feel a lack of organizational support when it concerns improving their own pedagogical training and competence. This is, according to the participants, likely to affect the overall quality and delivery of the courses.

Further, the current pilot education is not evaluated formally. The experts raise both a lack of short- and long-term evaluation as a weakness, as it makes it impossible to see whether certain training initiatives really prove to be successful in creating positive performance outputs for specific individuals within the program. It remains therefore unclear to what extent individual traits, experiences and specific training units contribute to a trainee becoming a successful pilot.

In relation to individual trainee performance, it was also discussed that the outcome, especially of the training onboard, is depending on the trainees' supervisors and their own willingness to learn to maximize the learning outcome. This allocates a lot of the responsibility to the actual trainee and might lead to different training outcomes based on the individual motivation. Further, as performance measures create a focus on quantity, for example number of pilotages executed, rather than quality, e.g., in terms of specific performance goals, individual trainees and their performance as pilots and service delivery may differ.

Lastly, the experts express that international cooperation with other pilot organizations currently is lacking, but that it would be of benefit to be able to identify lessons learned and potential improvements from other organizations.

Opportunities

The experts highlight that the current education has been developed over time, but that there are many opportunities both with regards to teaching methods and modalities, as well as to educational context that may be seized. At the moment, much of the training is focused on what goes wrong and how to prevent mishaps and errors. However, with a shift of focus towards what goes right within the operations, there is an opportunity to create new training content. As pilot operations only show few adverse events, such as incidents or near-misses, the number of pilotages that goes right is much higher and thus should offer many examples of what characterizes successful or positive performance.

Further, smart or novel technology has been highlighted as a potential support for training on shore and onboard. Eye-tracking, motion sensors and heart-rate measurements are named as some of the technologies that may support instructors and pilots in their work, e.g., through helping to identify certain information processing or spatial movement patterns, or for early identification of stress. It is also mentioned that real-life operations could increase in safety if psychophysiological measures could enable feedback to individuals, i.e., tell if a person is suffering from fatigue, or help to understand what it means to be alert in real-life settings.

Threats

The threats identified by the experts have been grouped into two larger areas; differences in background and types of trainees, and fear of being evaluated and reporting culture.

Pilot trainees normally have already had a career at sea within the merchant fleet. However, their background can differ quite widely, which might pose a challenge for instructors when students are not particularly receptive to new knowledge relying mostly on the experience from their previous career. Further, through the past years, there has been a decline in applicants, which means that the average trainee has less and often different experiences than what trainees used to have. Thus, it creates a need to increase the understanding of how certain skills and talents may affect training needs and outcomes, especially when trying to weigh in the importance of previous experience at sea and understanding how experience may, or may not, transform into expertise.

The experts raised the problem of learning from real-life events and situations, as they experience a fear of being evaluated among the active pilots in the organization. They partially associate this with the legal circumstances as, in case of an incident, pilots can be hold accountable for potential costs, thus any full disclosure or recognition of individuals' errors might lead to negative consequences. Therefore, pilots might be reluctant to report any potential error, which in turn limits and impacts on the ability to identify current or future training needs.

DISCUSSION AND CONCLUSION

This study set out to explore potential strengths, weaknesses, opportunities and threats in the professional education and training of marine pilots. The SWOT-approach was chosen to structure a focused group interview and to identify potential areas of improvement. Results show a professional education with similar strengths and weaknesses, opportunities, and threats as maritime educational programs within the academic system. As seen in Sellberg (2020), maritime instructors are recruited based on their extensive experience as working professionals. At the same time, there is a lack of effort in developing their pedagogical skills to handle the complexity of training and assessing new maritime pilots developing expertise in advanced maritime operations. Introducing new technologies, such as eye-tracking and different sensors, are seen as opportunities to strengthen maritime instructors in their work. However, it is important to acknowledge that introducing such technologies into current training practices need to be matched with opportunities for professional development. Ideally, maritime pilot training should be developed into a *professionalized teaching practice*. A professionalized teaching practice can be understood as a process through which teachers advance their levels of professional competence throughout their careers (Fernández, 2013). This process includes a learning period when entering the academic teaching profession, taking teaching and learning in higher education courses and the teachers' self-directed learning. This in turn implies that teachers recognize areas in the own teaching practice in need of improvement and works in a structured and scientific way to advance their teaching. We argue that conducting a SWOT-analysis with instructors can serve as a starting point for initiating a reflection on teaching and assessment practices.

In this study, the SWOT did not only show to structure the discussions among the experts, but also allowed them to explore and highlight issues on several different levels within the educational system, such as aspects related to the individual trainee, or organizational support and barriers. However, while the SWOT-analysis may support structured brainstorming, which can help to identify potential strategies for curricula or educational program design, it cannot serve as a stand-alone tool and should only be considered as a trigger for discussions, not as something generating a validated solution or pathway.

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EXPLORING STRENGTHS AND WEAKNESSES IN PROFESSIONAL MARINE PILOT EDUCATION

Gesa Praetorius, PhD

Charlott Sellberg, PhD

vti

SHIPPING AND MARINE PILOTAGE

- Shipping is the backbone of the globalized society and a high-risk system
- Pilotage is one of the foremost safety measure to ensure maritime safety and decrease risks
- Pilotage is carried out by certified marine pilots in sensitive areas and port approaches
- Marine pilots support merchant vessels with local expertise and enable effective communication with local and shore-based services

EVALUATION OF EYE-TRACKING AS SUPPORT IN SIMULATOR TRAINING FOR MARITIME PILOTS

- 3-year project financed by Swedish Transport Agency
- Investigate what it means to be a professionally competent marine pilot and how today's pilot training is organized to develop professional competence
  - What are the strengths and weaknesses of today's simulator-based maritime pilot training?
  - What methods can be used to identify tacit knowledge and visual expertise of experienced pilots useful in the pilot training?
  - What didactic methods and technical support can be used to transfer tacit knowledge and visual expertise from experienced pilots to pilot students efficiently and reliably?
  - What needs for technical and pedagogical competence development do instructors need when implementing new technology in the pilot training?

SWOT-ANALYSIS

- Strategic planning tool to achieve fit between internal characteristics of an organization (Strengths, Weaknesses) & external contextual factors (Opportunities, Threats)
- Tool to structure brainstorming in expert groups
- Applications in a wide variety of domains and disciplines
  - Successful bridge team organization (Arslan & Er, 2008)
  - Evaluation of VR technology for training firefighters (Engelbrecht et al., 2019)
  - Trainee perceptions and self-evaluation in surgical training (Wankhede et. al, 2021)

METHODOLOGY

- 3h online focus group with 5 marine pilots and instructors within the pilotage education
  - 13-23 years experience as pilot
  - simulator-based training, non-technical skill training, on-the-job training
- Use of Miro to facilitate interaction between moderators and participants
- 30-40 minutes discussion per ”aspect”


intressantare
en god blandning där mycket praktik sockras med teori
utbildningen ligger tätt ihop med yrkesrollen "verkligheten"
Varvar teori och praktik
Teori varvat med praktik
Utbildning ombord på fartyg. olika teknisk utrustning/kvalitet
Praktisk tillämpning av teoretiska föreläsningar
Utbildning ombord på fartyg med olika besättningar
Kursupplägget är till stora delar fast men vi anpassar efter frågorna som dyker upp för att möta behovet
Det är kursledarna som bestämmer detaljerna i innehållet
kontinuitet i kursutveckling
som är kursledare just nu jobbar som lotsar till vardags.
Transparens bland instruktörerna, att man delar med sig av sina "misstag"
Lotsar som utbildar lotsar
att lotsar utbildar lotsar
"Lärlings system" Att gå tillsammans med erfaren ombord på fartygen.
Ta lärdom av varann och instruktörerna inom MRM
Ser hur erfaren uppträder/gör
Bred kompetens
Vi kan ge många enkla och tydliga exempel från verkligheten utan att det blir för mycket story telling
Vi använder deltagarnas bakgrund och erfarenhet i kursen
Lätt att motivera kursdeltagarna eftersom alla är väldigt intresserade.
Eleverna är mycket motiverade
Instruktörerna träffar eleverna från grundutbildningen även efter flera år och kan få bra feedback på kursinnehållet.
Väldigt olika erfarenhet med till lotsyrket, största delen sjörelaterad.
Erfarenhet med in
Egenintresse från eleverna
Det är i nuläget ganska små grupper. max 10 pers vilket gör det personligt.
Anpassad utbildning efter kunskap som gruppen besitter

STRENGTHS AND WEAKNESSES

- Balance between practice and theory
- Varying training context and modalities
- Open dialogue which enables the use of experience and expertise of instructors and trainees within the training
- All instructors are actively working as pilots

- Lack of organizational support for pedagogical training
- Lack of evaluation of the training (short-term, long-term)
- Performance measures foster quantity over quality
- Trainee’s development heavily depending on supervisor
- Lack of means for organizational learning

OPPORTUNITIES AND THREATS

- Potential to learn from the positive as pilotage generally offers many examples for successful performance
- New technology to support instructor work (evaluation, gaze patterns)
- Technology can potentially be applied in learning environment and during work

- Experienced trainees might be reluctant to learn new knowledge
- New type of trainee, often with less experience
- Problematic legal framework which hinders learning culture and fosters reluctance to report errors

DISCUSSION AND CONCLUDING REMARK

- SWOT-analysis useful tool to explore professional pilot education
- Complexity of professional training and assessment requires both expertise in pilotage and in pedagogy
- Organizational support is a necessity to allow developments in professional education
- Evaluation is the basis for improvement (short-term & long-term, individual – group)
- New technology opens for new ways of assessing and understanding the work of a professional pilot
- Organizational learning culture with emphasis on what constitutes successful performance

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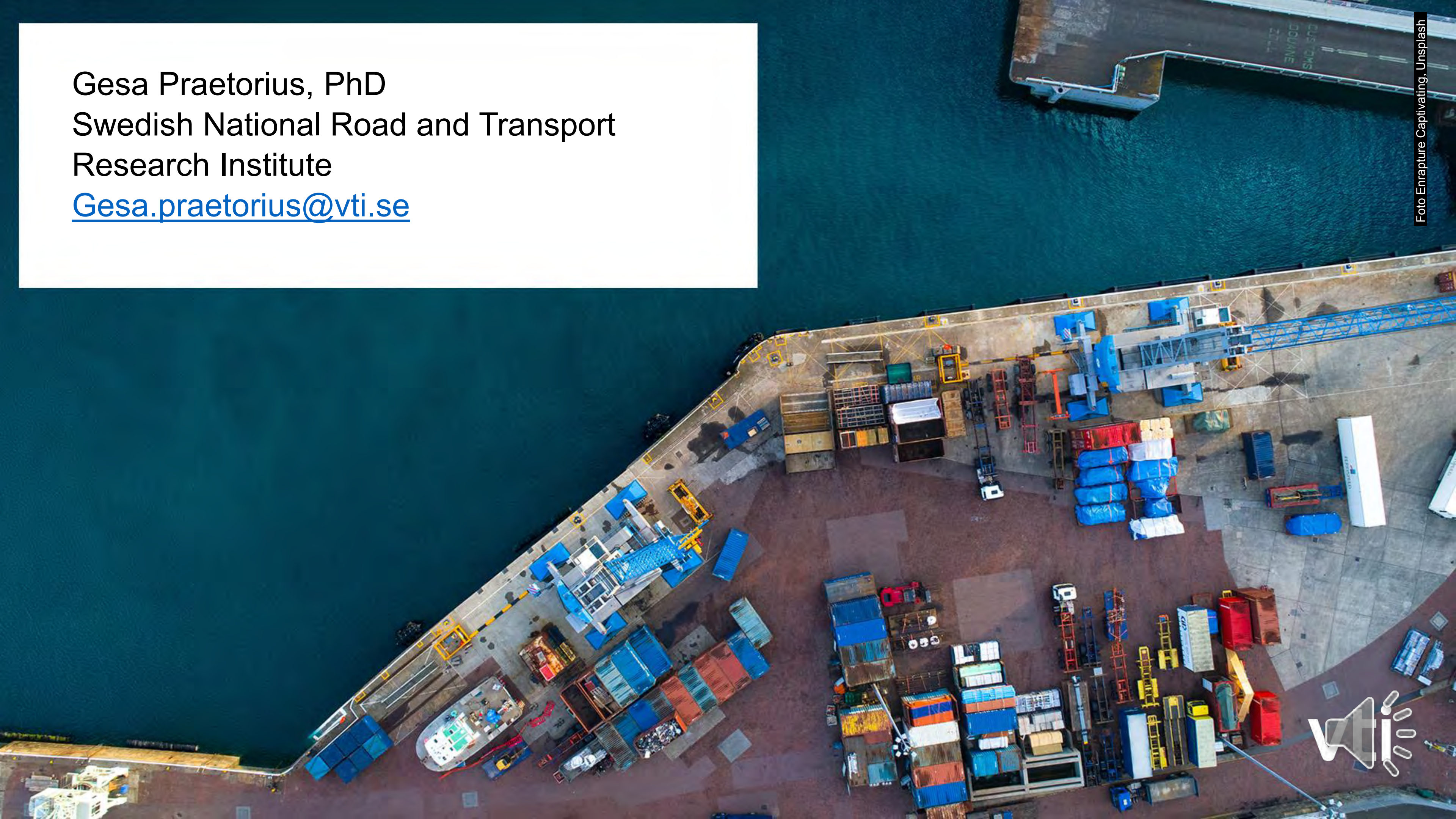

Foto Enrapture Captivating, Unsplash

RESEARCH REPORT 5

Assessing non-technical methods for transferring tacit knowledge in safety-critical systems: A study on Maritime Pilot Training

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ASSESSING NON-TECHNICAL METHODS FOR TRANSFERRING TACIT KNOWLEDGE IN SAFETY-CRITICAL SYSTEMS: A STUDY ON MARITIME PILOT TRAINING

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Abstract

A safety-critical system is a system whose failure or malfunction will have serious consequences and typically include, healthcare, aerospace, naval operations, nuclear or process industries, and military systems. Safety-critical systems also show a high level of automation and are to a high degree dependent on tacit knowledge embedded within the workforce. It is important to an organization to find methods to manage tacit knowledge transfer and thereby establishing resilience over time. Maritime pilotage is a safety-critical segment of the maritime industry to assure safe, economic, and sustainable naval operations. During the maritime pilot training the maritime pilot student acquires trade specific skills, often in the shape of tacit knowledge, primarily when interacting with other more experienced maritime pilots. The purpose of this study is to improve the maritime pilot training to mitigate increasing requirements of safe, economical, and environmentally sustainable shipping operations. The aim of the study was to locate, catch, crystallise, document, and describe non-technical methods of tacit knowledge transfer during the different elements of the maritime pilot training. This study is a mixed-method study, based on observations, interviews, questionnaires, and document analysis. In total, 21 participants were included in the study, consisting of maritime pilot students, less experienced but licensed maritime pilots, and highly experienced master maritime pilots. The results show that a substantial amount of tacit knowledge transfer occurs during on-the-job activities. Such activities are predominantly taking place in social settings and are not consistently documented or systematically utilized within the organization.

Keywords: Tacit knowledge, Implicit knowledge, Maritime education and training, Maritime pilot.

1 INTRODUCTION

1.1 Safety-critical systems

A safety-critical system (SCS) is a system where failure or malfunction can cause fatal injuries to people, severe damage on equipment or property, substantial economic losses or result in environmental harm. SCS typically include domains such as healthcare, aerospace, naval operations, road transportation, nuclear and process industries, and military systems [1]. However, an increasing number of applications in different parts of the society is becoming extensively automated and digitalized. Failure or malfunction of such applications can give as a secondary effect disruption of normal activities, thus, resulting in an increased risk of harm. Furthermore, even if a SCS is per se designed not to lose more than one life per billion hours of operation [2], the consequences of such a malfunction can be disastrous.

1.2 Tacit knowledge

To perform well, an organization is dependent on the employees' competence. In an organization exposed to competition, knowledge is a critical asset [3]. Studies have shown that a lot of explicit and implicit knowledge in an organization is hidden and synthesized among employees [4], [5]. Employees flow, over time, in and out of the organization due to termination of the employment, new recruitments, organizational change, or retirements, subsequently leaving a hollow organization behind. People who have worked in an organization for many years possess extensive knowledge on how to perform their working tasks. There is a significant risk that important knowledge disappears when experienced people leave the organization [6]. Tacit knowledge develops through practice over a long period of time. It is implicit in nature and not easily accessible for articulation in speech or in writing [7]. It is often difficult to describe how a complex working task is to be performed without explicitly showing how to perform that task. An important distinction rests between knowledge that an individual has difficulties in articulating (tacit) or are unwilling to articulate (hidden). The fact that a person is unwilling to articulate knowledge could be the risk of others taking over that person's working tasks, or if the knowledge becomes public that it could result in negative consequences for the individual or the organization. Studies of tacit

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knowledge have been implemented mainly in large information organizations such as IT-companies, banks, service companies, and consulting firms. Furthermore, within an organization formal as well as informal methods can be used to transfer tacit knowledge [8]. Literature, instructions, standard operating procedures, and manuals are examples of formal methods to transfer knowledge. Such knowledge can be expressed as propositional knowledge or "knowing that" [9]. Mentoring and apprenticeship, coaching, job rotation, and personal networking are examples of informal methods to transfer tacit knowledge [8]. Such knowledge can be expressed as the creation of procedural knowledge or "knowing how" [9]. However, there is a need to improve many organisations in terms of their ability to acquire and transfer tacit knowledge [10], [11].

1.3 Safety-critical systems and tacit knowledge

Few studies are found on tacit knowledge in a SCS. For example, in the process industry experienced operators and shift teams stand for vital knowledge about operation and control of the plant, using explicit and implicit knowledge. Larsson et al. [12] discuss in relation to the nuclear sector the importance of preserving competence within the organisation by taking care of older employees' competence before retirement and when generational shifts occur. Engstrom [13] also shows for the nuclear sector, how operators' skills and experience can act as a safety method for process control, especially when handling unexpected events. The methods for knowledge transfer that are used in process industry are primarily internship and teamwork occurring within shift teams [12]. In a SCS, knowledge of a one individual is mainly transferred to others based on socialization [14]. Such knowledge transfer, which may take several years, are seldom documented.

1.4 Maritime pilotage

1.4.1 General

Maritime pilotage is a safety-critical and crucial part of the maritime industry to assure safe, economic, and sustainable naval operations. The maritime pilot (hereafter pilot) provides, based on extensive local knowledge, navigational guidance to mariners on specific waterways such as harbours, river mouths, or canals as well as on the open sea. The pilot interacts with the bridge crew of the piloted vessel providing advisory information in terms of navigation, specific properties of the water in terms of depth, obstacles, tides, infrastructure etc., and assists during tugging, birthing, and mooring operations [15].

1.4.2 Maritime Pilot Training

The Swedish Maritime Administration (SMA) is responsible for the maritime pilotage within Swedish territorial waters and employ some 230 pilots. These pilots perform 33 000 missions annually [15]. The SMA is furthermore responsible for the Maritime Pilot Training (MPT) responding to the requirements of training, re-training, and continuous training of the pilots. Experienced Masters from the shipping industry can, following application and evaluation, be selected for the MPT.

The MPT has a duration of approximately one year and contains three parts. (1) An Introductory course (duration 1-3 months) that covers employment conditions, safety, regulations, the SMA organisation, and general pilotage procedures etc. (2) A Basic MPT course (duration 6 weeks) that contains manoeuvring, navigation, Bridge Resource Management (BRM), duties of the governmental officer, boarding operations, hoisting, and hypothermia etc., where some training is performed in simulator environment and some in the real maritime environment. The Introductory course can overlap the Basic MPT. (3) A Local Training Plan (LTP) (6-12 months depending on location) where the maritime pilot student (hereafter student) acquires knowledge by participating in 50 actual missions in cooperation with a certified pilot who is functioning as a supervisor. During the LTP the knowledge construction is characterised by apprenticeship. The LTP concludes with an examination where the student becomes a certified pilot holding a basic level Guide note (Level 1). The goal over time is to gain experience to reach the highest-level Guide note (Levels 4-5). Then non-restricted missions can be performed. Each third year, re-training containing rotating focus areas is conducted. Simulator training and BRM is used to provide this training. Furthermore, the SMA also conducts continuous training such as training for open sea pilotage (Red card e.g.) or the transition to other SMA vessels such as ice breaking ships.

1.4.3 Situated learning

During the MPT, a considerable proportion of the knowledge transfer occurs in a situated learning environment [8]. In a situated learning environment, an individual acquires knowledge and professional skills by interacting with others. Apprenticeship, community of practise or guided experience are examples of such interaction where learning “takes as its focus the relationship between learning and the social situation in which it occurs" [16]. The MPT requires an extensive effort in terms of time, resources, infrastructure, funding, and individual and organizational commitment. The transfer of knowledge is therefore a key element to meet the specified MPT curriculum.

Initial observations, naval experience of the first author, and document analysis has shown that the MPT was accomplished, to a large extent, by experienced pilots sharing their expertise in social settings [17]. This knowledge sharing is however not consistently documented and expressed in pedagogical or didactical terms in the MPT curriculum.

2 PURPOSE AND AIM

The purpose of the study was to identify methods to improve the MPT in order to mitigate increasing requirements of safe, economical, and environmentally sustainable shipping in Swedish territorial waters. The aim of the study was to locate, catch, crystallise, document, and describe non-technical, informal, methods of tacit knowledge transfer during the MPT.

3 METHODOLOGY

The study was performed as a mixed-method study to assess where, in time and space, tacit knowledge was transferred during the MPT. Observations, interviews, questionnaires, and document analysis were used for the collection of data. The data collection was conducted during a complete MPT course, which is equal to approximately one year, but also by complementary interviews and observations before and after the MPT.

3.1 Participants

In total 21 participants were included in the study. The participants consisted of 8 students, 7 less experienced but licensed pilots, 5 licensed experienced master pilots also functioning as instructors, and 1 administrator who also functioned as SMA coordinator for the present study. The mean age was 46 years with a standard deviation of 8 years. All participants were males and operated from 7 different pilot stations.

3.2 Observations

During the study, 3 pilot stations were visited. Observations were performed during classroom- and simulator-training at the SMA central training facility, at pilot stations situated in harbor environments, and during actual missions into and out from a major international harbor. The observations were deployed as passive participating observations [18], [19] combined with interviews and distribution of questionnaires. Since the first author had applied experience from the maritime domain, passive participating observations occasionally evolved into moderate participating observations caused by participant invitations to discuss domain specific topics. At suitable occasions, such as intermediate low activity periods, an observation protocol was filled out.

3.3 Interviews

Semi-structured interviews [20], based on a specified interview guide, were performed when time and place during the MPT permitted. Interviews were held individually as well as in group settings with the purpose of exploring non-technical methods for transferring tacit knowledge. Interviews were recorded electronically and thereafter transcribed. A thematic reflective inductive analysis [21] was performed to organize the data set from the interviews. The transcripts were initially read through to create an overview of the content and the components of the data in terms of patterns. The data was coded and by iteration refined, followed by the organization of codes into relevant themes. Next, the emergent themes were reviewed in relation to the data and the codes. The last step was to define the emerging themes and describe them further in their meaning.

3.4 Questionnaires

A questionnaire containing 20 questions (six-point Likert scale) was distributed to students, pilots, instructors, and staff responsible for the MPT administrative support. The six-point even scale was selected so no neutral center option could be chosen [22]. The purpose of the questionnaire was to assess data such as age, experience, and certificates of the participating pilots etc. Furthermore, the purpose was also to gather their assessments on how and where tacit knowledge, in terms of non-technical methods, was transferred in the MPT. The questionnaire was designed without underlaying deductive themes thus enabling emerging themes to become visible.

3.5 Document analysis

Document analyses can be used to provide background and context, to identify additional questions, to provide supplementary data, to track evolution, to verify findings (triangulation), and to be used as a method of gathering data when other methods are no longer available [23]. A systematic document analyses was executed including assessments of training curriculums, course literature, operating procedure descriptions, and intranet data bases. Printed and electronic documents, illustrations, and films were also included in the analyses. The purpose of the document analysis was to identify descriptions of non-technical methods for transferring tacit knowledge.

The emerging data was examined, categorized, and interpreted to elicit further meaning and understanding of the topic [23], [24]. A thematic inductive analysis was used to code and organize the data into themes. Additionally, the higher level organizational pedagogical scope was also analyzed to verify if the organization provided the MPT as expected. Relevant documents were also discussed with the MPT administrative personnel as well as with students, pilots, and instructors.

4 RESULTS

The result presents qualitative as well as quantitative data from observations, interviews, questionnaires, and document analysis.

4.1 Observations

4.1.1 Introductory course

In total, 25 hours of observation during 3 training days, was performed and documented. During the observed parts of the Introductory course much of the knowledge was transferred in non-situated environments (75%) and in the form of propositional knowledge (76%). This type of knowledge was transmitted in the form of lectures, literature, written instruction, data base contents, and information derived from the SMA intranet. Students also, to a lesser extent, participated in practical hands-on training, such as conducting safe sea transports to and from the piloted vessel, boarding exercises and introduction to the pilotage station selected for their later stationing. Therefore, knowledge transfer also occurred in situated settings (25%) and in the form of procedural knowledge (24%). See Table 1 below.

4.1.2 Basic MPT

In total, 76 hours of observation during 8 training days, was performed and documented. During the observed parts of the Basic MPT much knowledge was transferred in situated settings (61%) and in the form of procedural knowledge (69%). Typical activities were hands-on training with fellow students and instructors participating in simulators, maneuvering miniature ships in a specific training facility as well as boarding and hoisting operations. Propositional knowledge transfer thereby complemented procedural knowledge transfer. Here the students reflected individually and/or in groups to crystalize new propositional knowledge. Such knowledge was then merged with hands-on training to form procedural knowledge which can be expressed as the development of basic skills. Knowledge transfer also occurred in non-situated settings (39%) and in the form of propositional knowledge (31%). See Table 1 Below.

4.1.3 LTP

In total, 18 hours of observation during 2 training days, was performed and documented. Much of the knowledge was transferred in a situated learning environment (78%) and as procedural knowledge (85%). The student become to a large extent embedded in pilotage operations and over time became a member of a community of practice. Furthermore, the LTP takes place at the specific pilotage station where the student is scheduled to be based. Skill is developed during the LTP, e.g., skill that is not only domain specific but also specific for the specific pilotage station including waters, infrastructure, weather, and tonnage. Again, procedural knowledge was the predominant method for transferring knowledge even if the student returned to non-situated settings (22%) during intermediate periods acquiring propositional knowledge (15%). See Table 1 below.

Table 1. Knowledge transfer methods in percentage during the Introductory Course (INTRO), the Basic MPT (BASIC), and the Local Training Plan (LTP) based on observation protocols

	Situated	***Non-situated***	***Procedural***	***Propositional***
INTRO	25%	75%	24%	76%
BASIC	61%	39%	69%	31%
LTP	78%	22%	85%	15%

4.2 Interviews

The transcribed interviews resulted in two types of findings. First, the purpose of assessing methods of transferring tacit knowledge was reached and, secondly, new insights were obtained on the properties of the MPT. The inductive thematic analysis resulted in two main themes: (1) Propositional learning and (2) Procedural learning.

4.2.1 Propositional learning

This theme was based on the following sub-themes: Literature, Lectures, Instructions and procedures, and Information and communication tools. Students consistently expressed a need for relevant literature, adapted for the specific trade of pilotage and for Swedish operations. Such knowledge was transferred during the Basic MPT, however not generally in an organized and documented form. Furthermore, propositional knowledge was present before, during, and after simulator sessions. This knowledge often came in verbal form by instructors or in visual form shown on screens or on whiteboards.

4.2.2 Procedural learning

This theme was based on the following sub-themes: Apprenticeship, Guided experience, Community of practise, On-the-job-training, Trainee, Mentorship, Practise, and Coffee break talks. The students reported to a high degree the value of hands-on training, especially during simulator sessions. During actual supervised training pilotage, the LTP, most of the students stated that classroom, as well as simulator training, was of value but operating in the real world, on the job, was essential for the development of a new profession. Many students described the development of their own specific course booklet, a quick reference guide, as important for their progression towards becoming pilots. The course booklet is the only clearly visible attempt to document tacit knowledge transfer during the MPT.

4.3 Questionnaires

The results from the questionnaires showed a high similarity to the themes from the observations and from the interviews. During the Introduction course, propositional knowledge transfer was predominant and was furthermore executed mostly in non-situated environments. Student assessments also showed that procedural knowledge was transferred but to a lesser extent. During the Basic MPT, pilot assessments became more inclined towards procedural knowledge transfer and was performed in a mix of situated and non-situated environments. The Basic MPT is a hybrid training environment where propositional knowledge is fed into hands-on training in a social environment. Thereby enabling the creation of procedural knowledge. The LTP is per se a situated learning setting which was also reflected in the pilot assessments.

4.4 Document analysis

The result from the document analysis showed to a very high extent that material for transferring propositional knowledge was present in several ways. Course literature, curriculums, handouts, database material, manuals, and written and/or filmed material e.g., contained propositional knowledge. However, material for transferring procedural knowledge was inconclusive or not to be found.

5 CONCLUSIONS

We often know more than we can tell or explain to others. Some knowledge is so deeply embedded that we do not think about what we know and what we are doing – we just do it. This is tacit knowledge, skill, or expertise, which has taken many years to achieve.

This study resulted in improved understanding of where, when, and how tacit knowledge is transferred during maritime pilot training. The results found, provide opportunities to improve the tacit knowledge transfer in terms of efficiency, pedagogics, and didactics.

Maritime pilot training is to a large extent dependent on situated learning, learning that takes its focus on the relationship between learning and the social situation containing a specific environment for that learning. Students acquire much of their professional skill by interacting with other pilots in a social process. Competence (applied knowledge) is constructed in cooperation with fellow students as well as with experienced pilots. Students become accustomed to knowledge that is embedded within the pilotage workplace context. Domain specific procedures, techniques, tactics, norms, and problem solving are constructed during all phases of the maritime pilot training.

Propositional knowledge contrasted by procedural knowledge is also a central element of the maritime pilot training. The former as well as the latter were present in the situated learning environment together or separately or in non-situated learning environments. Students constructed propositional knowledge as individuals or in study groups. Furthermore, students could improve their hands-on skills, in simulators e.g., individually or in groups.

Observations, interviews, questionnaires, and the document analyses resulted in similar findings: students apricate and acknowledge procedural knowledge transfer in situated settings.

This study can serve as a pilot-study to enhance the understanding of tacit knowledge transfer in general and, specifically, in terms of non-technical transfer. A consistently increasing number of observations and their duration can improve the empirical result of coming studies. This is to a high extent valid for the local training plan which is a major part of the training to become a pilot. During this part the student construct substantially, the procedural knowledge required for the coming profession.

Future research efforts can be allocated to continue the study to improve the existing non-technical transfer methods as well as designing new ones. A specific element of interest in this context is to further study the course booklet each student develops during the training. This booklet serves two purposes: assisting the student in constructing knowledge as well as being the only clearly visible method of documenting tacit knowledge.

ACKNOWLEDGEMENTS

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Assessing Non-technical Methods for Transferring Tacit Knowledge in Safety-critical Systems: A Study on Maritime Pilot Training

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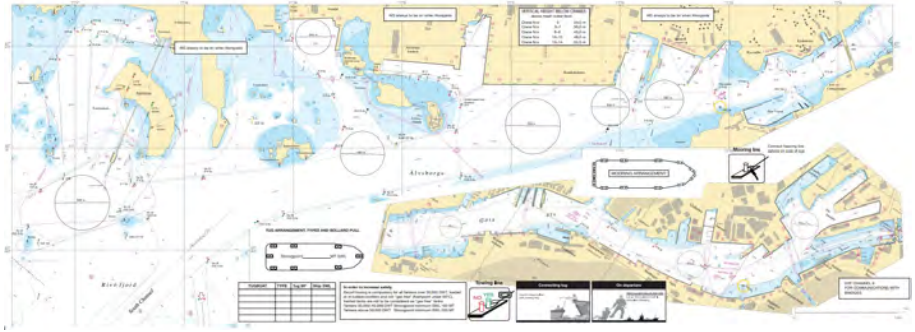
AGENDA

- Introduction
- Purpose and aim
- Methodology
- Participants
- Results
- Conclusions

Ports Australia 2018

Swedish Maritime Administration 2022

The Sea Lad 20222022



Swedish Maritime Administration 2022

INTRODUCTION
Pilotage

- Pilotage is a crucial part of the maritime industry to assure safe, economic, and sustainable naval operations
- The maritime pilot (hereafter pilot) provides expertise and navigational guidance to mariners on specific waterways such as harbors, river mouths, or canals as well as on the open sea
- The pilot interacts with the crew of the piloted vessel providing advisory information in terms of navigation, specific properties of the water in terms of depth, obstacles, tides, infrastructure etc., and assists during tugging, birthing, and mooring operations

INTRODUCTION
Pilotage

- The Swedish Maritime Administration is responsible for pilotage within Swedish territorial waters and employ some 230 pilots
- These pilots perform 33 000 missions annually
- The Swedish Maritime Administration is furthermore responsible for the Pilot Training Programme answering to the requirements of basic training, re-training, and continuous training of their pilots
- Experienced sea captains can after application and evaluation be selected for the Pilot Training Programme

INTRODUCTION
Pilot Training Programme

- The Pilot Training Programme has a duration of approximately one year and contains three parts:
    - Introductory Training (duration 1-3 months)
    - Swedish Basic Training for Maritime Pilots (duration 6 weeks)
    - Local Training Plan (duration 6-12 months)
- The programme includes lectures, simulator sessions, ship handling, and on-the-job practise
- After examination, a Pilot Certificate as well as a Pilot License (Level 1) is issued
- As the pilot gains experience, a Pilot License level 2-5 will be issued


Sjöfartsverket 2022/Chalmers 2022


Sjöfartsverket 2022


Sjöfartsverket 2022 / Chalmers 2022

INTRODUCTION
Safety-critical systems

- A safety-critical system is a system where failure or malfunction can cause fatal injuries to people, severe damage on equipment or property, substantial economic losses or result in environmental harm
- Safety-critical systems typically include domains such as healthcare, aerospace, naval operations, transportation, nuclear and process industries, and the military

INTRODUCTION
Knowledge in organizations

- To perform well, an organization is dependent on the knowledge and competence held by its members
- Knowledge within an organization is stored in individuals, in the collective, in the organizational infrastructure, or outside the organization
- Members who have worked for a long time possess extensive knowledge on how to perform their working tasks
- Experienced members also have increased abilities to solve non-normal or unexpected events
- Transferring knowledge between members of the organization is vital

INTRODUCTION
Knowledge in organizations

- Members, including their knowledge, flow in and out of the organization due to market dynamics, new recruitments, organizational change, retirements etc
- There is a risk that knowledge disappears when experienced people leave the organization
- Outsourcing, horizontal integration, or lean strategies also increase the risk of knowledge drainage
- Risk of creating a hollow organization as a result

INTRODUCTION
Tacit knowledge

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- Knowledge can be explicit, implicit or combinations thereof
- Explicit knowledge is formal propositional knowledge found in literature, instructions or manuals and can be readily articulated, codified, stored, accessed, and transferred ("Knowing that")
- Implicit (hereafter tacit) knowledge is informal procedural knowledge such as skill, experience, intuition etc and is not easily accessible for verbalization ("Knowing how")
- Tacit knowledge is mainly transferred by socialization such as apprenticeship, practise, or internship, and in situated environments
- Tacit knowledge is mainly transferred in non-technical ways
- Explicit and tacit knowledge is present in the organization simultaneously and complement each other

INTRODUCTION

Safety-critical systems and tacit knowledge

- Few studies are found on tacit knowledge in safety-critical organizations
- Results from studies on nuclear- and process-industry show that experienced workers have extensive explicit and implicit knowledge of the control and operation of their systems
- Such knowledge is of great importance during non-normal operations
- Tacit knowledge is mainly transferred through socialization, but the procedures and the result is seldom documented

PURPOSE AND AIM

- The purpose of the study was to identify ways to improve the Pilot Training Programme adhering to increasing requirements of safe, economical, and environmentally sustainable shipping in Swedish territorial waters
- The aim of the study was to locate, catch, crystallize, document, and describe non-technical informal methods of tacit knowledge transfer during different parts of the Pilot Training Programme

METHODOLOGY
Explorative mixed-method study

Performed during Introductory Training, Swedish Basic Training for Maritime Pilots, Local Training Plan.

Observations:

- Passive participating observations
- Class-room lectures, simulator sessions, Local Training Plan, pilotage missions
- Students, instructors, administrative personnel

Interviews:

- Semi-structured interviews
- Thematic inductive analysis
- Students, instructors, administrative personnel

METHODOLOGY
Explorative mixed-method study

Performed during Introductory Training, Swedish Basic Training for Maritime Pilots, Local Training Plan.

Questionnaires:
- Six-pint Likert scale assessments
- Distributed at 3 pilot stations
- Students, instructors, administrative personnel

Document analysis:
- Systematic document analysis
- Training syllabuses, manuals, literature, didactical and pedagogical plans, regulatory documents
- Students, instructors, administrative personnel

PARTICIPANTS

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- 21 participants in total
- 8 students
- 7 less experienced but licensed pilots
- 5 experienced licensed master pilots also functioning as instructors
- 1 administrator functioning as coordinator for the present study
- Mean age was 46 years with a standard deviation of 8 years.
- All participants were males
- 7 different pilot stations

RESULTS

Observations

Introductory Training:

25 hours of observation, 8 students, 5 instructors, 2 administrative personnel

- 24 % knowledge transferred as procedural knowledge
- 25 % knowledge transferred in a situated environments

Swedish Basic Training for Maritime Pilots:

76 hours of observation, 8 students, 5 instructors, 2 administrative personnel

- 69 % knowledge transferred as procedural knowledge
- 61 % knowledge transferred in situated environments

Local Training Plan:

18 hours of observation, 2 students, 2 instructors, 1 administrative personnel, 1 pilot boat crew

- 85 % knowledge transferred as procedural knowledge
- 78 % knowledge transferred in situated environments

RESULTS
Interviews

The interviews resulted in data that was recorded, transcribed, and organized into preliminary themes which were further combined organized into Theme 1 and 2.

Theme 1 Propositional Learning
Knowledge was transferred by using the following preliminary themes:
- Literature, Lectures, Instructions and procedures, Information, and communication tools

Theme 2 Procedural Learning
Knowledge was transferred by using the following preliminary themes:
- Apprenticeship, Guided experience, Community of practise, On-the-job-training, Traineeship, Mentorship, Practise, and Coffee break talks

RESULTS
Questionnaires

The combined result from the questionnaires showed high consistency (triangulation) with results from observations and from interviews.

- Tacit knowledge was transferred mainly in social settings
- Tacit knowledge was transferred mainly during the Local Training Plan
- Interacting with more experienced pilots assessed as vital by students

RESULTS

Document analysis

CHALMERS

Course literature, curriculums, handouts, database material, manuals, and written or filmed material during the Swedish Maritime Administration Pilot Training Programme were used as sources of data.

- Methods and means for transferring propositional knowledge were distributed during all three parts of the Pilot Training Programme
- Methods and means for transferring procedural knowledge was found inconclusively described or not documented at all
- The Local Navigation Booklet, containing notes on navigational charts, courses, distances, turn radiuses, points of interest, and metrics for tugging etc created by the student during the Local Training Plan, was the only non-technical method for transferring tacit knowledge identified

CONCLUSION

- Tacit knowledge is mainly transferred during the Swedish Basic Training for Maritime Pilots and during the Local Training Plan
- The Pilot Training Programme is to a large extent dependent on situated learning such as community of practice
- Students acquire much of their skill by interacting with others in a social process
- Students develop skills to a high degree in simulators, combining propositional and procedural knowledge
- Methods for transferring tacit knowledge are not sufficiency described nor documented in the Swedish Maritime Administration course material

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RESEARCH REPORT 6

Developing visual expertise in a simulated environment: A case of maritime pilots in training

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Developing visual expertise in a simulated environment: A case of maritime pilots in training

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Abstract

This study connects to an ongoing discussion about the limits and affordances of simulators as realistic and relevant contexts for professional learning, in this case in the development of visual expertise. Through a socio-cultural approach to the development of visual expertise, and multi-modal interaction analysis of video recorded training sessions, the analytical focus is directed towards exploring maritime pilot trainees' talk about imperfections and inconsistencies in the virtual environment during exercises in a high-fidelity bridge simulator. Findings show that trainees are able to flexibly adapt to methodological and technological challenges when maneuvering a simulated vessel, and that challenges of training in a virtual environment lead to enriched conceptual, methodological, and technical knowledge regarding visually demanding and ambiguous navigation situations.

Background

A maritime pilot is an expert navigator, specialized to support maritime officers to maneuver their vessel in a challenging maritime territory. Through the maritime pilot's intimate knowledge of the fairway and experiences of maneuvering different types of vessels, the maritime pilot contributes to ensuring that maritime and environmental safety can be maintained when vessels operate pilotage-obliged water (e.g., Lützhöft & Nyce, 2006). In addition to skills in ship maneuvering, navigation, and seamanship, the ability to interact with various types of technologies, professional cultures and crews is also required as each ship is unique in terms of equipment and instruments. Central to the maritime pilot's expertise is the skilled perception, interpretation, and evaluation of the domain's visual materials (cf. Gegenfurtner et al. 2019). Historically, maritime pilot training is based on a long tradition of apprenticeship on board ships, where the pilot's competence is developed through years of experience traveling a specific territory. Today, maritime pilot training is a one-year specialization program, organized by national maritime administrations and undertaken by master mariners with extended experience of working as marine officers. The training program consists of three parts. First, there is an introduction period where the applicant goes through a recruitment process for a probationary employment as maritime pilot. After admission to the program, there is a package of basic courses, addressing a wide range of professional aspects of working as a maritime pilot, including legal and administrative course contents, simulator-based training of teamwork skills as well as advanced navigation and maneuvering training. As a final part, the maritime pilot trainee undertakes on-the-job training and performs simulator-based tests of competence. When passing these tests, the maritime pilot trainee becomes a certified maritime pilot, and the probationary employment transitions into a permanent position.

Considering the new ways of training made possible by simulations, concerns have been raised that simulator-based training might cause maritime pilot trainees to learn to manipulate a simulated model rather than to handle the conditions that apply on board a real ship, causing so called *negative skills transfer* (Hontvedt, 2015). In Hontvedt (2015), findings show how the lack of realism during simulations had negative consequences for the trainees, since imperfections and inconsistencies in the simulator environment came in conflict with their professional vision, and, as a result, the trainees changed their way of working to adapt to shortcomings in the simulator environment. As Rystedt and Sjöblom (2012) point out in a study on simulations in healthcare: no matter how technically advanced the simulator is, there will always be "glitches", i.e., imperfections and inconsistencies between the simulator environment and the work context. In Rystedt and Sjöblom (2012) these glitches were systematically addressed and handled during training, as the participants mutually orientated to the relevant similarities with clinical practice while ruling out of task irrelevant dissimilarities. Similar findings have been reported during dental training, where glitches served as an instructional resource to reason about simulations in relation to clinical practice (Hindmarsh et al., 2014). In master mariner training (blinded for review), findings show how simulator instructors are working actively to fill in missing aspects of the simulation during training on a bridge simulator, and by doing this, they are mitigating the risks of negative skills transfer. Moreover, studies concerned with the development of visual expertise have shown that skills transfer might be a too simplistic way of grasping the idea of professional learning across technologies (Lehtinen et al. 2020). Using the metaphor of different layers of conceptual change for professional learning in a biomedical setting, Lehtinen et al. (2020) show how experts learn new ways of conceptualizing the unfamiliar conditions of working with new visualization technologies for doing diagnosis. In this case, learning goes beyond simply transferring knowledge between work settings. Rather, is a matter of adapting to new methods and working conventions, while the basic principles, the biomedical concepts and procedures these expert need to understand remained stable across work settings. In this process, Lehtinen et al. (2020) found that the experts spent significant time analyzing the relevant aspects of unfamiliar conditions in order to adapt their familiar working methods to the new visualization technology.

Aim and research questions

Taking the multi-layered nature of professional skills into account, this study continues to explore tensions between simulator fidelity and professional learning further through a socio-cultural perspective on the development of visual expertise (Gegenfurtner et al., 2019). The aim is to carefully examine the risk of negative skills transfer when training in a simulator environment, directing the analytical focus towards maritime pilot trainees' talk about imperfections and inconsistencies in the virtual environment during exercises in a high-fidelity bridge simulator. The point is scrutinizing to what extent and how they thematize such tensions between settings. The following research questions are in focus: a) how do trainees handle imperfections and inconsistencies in the virtual environment during visually demanding tasks? and b) what are the implications of handling imperfections and inconsistencies for the development of visual expertise in maritime pilot training?

Method, data, and analytical approach

With the analytical attention directed towards naturally occurring dialogues between trainees, the research design utilizes a videography approach (Knoblauch & Schnettler, 2012). Hence, our study draws on focused ethnography at a Scandinavian simulator-center and, in addition, video documentation of a course on advanced ship handling in maritime pilot training. The analytical approach involves multimodal interaction analysis. The approach is dedicated to the study of naturally occurring phenomena, that is, instead of designing or controlling the learning activities under study, the purpose is to capture the everyday social interaction that normally takes place in an instructional setting. The focused ethnography in this case involves two visits to the simulator center before starting to collect video data. The purpose of these visits was to gain a basic understanding of maritime pilot training and identifying activities for closer analysis. In addition, a focus group interview with five experts on maritime pilot training was carried out. Collected video recorded data captures four full days of simulator-training on three full mission bridge simulators and include all stages of training: from the pre-simulation introduction (the so-called briefing), through the simulated scenario and the post-simulation debriefing. Thus, the data corpus consists of fieldnotes, interview transcripts and approximately 130 hours of video recorded simulator-based training.

The video records of simulations form the basis for multimodal interaction analyses. In multimodal interaction analysis, the unit-of-analysis consists of verbal utterances, bodily conduct, and interaction with material and digital objects, observable through turns of talk between participants (Pirini et al. 2018). In the first step of analysis, the video recordings were reviewed and catalogued to obtain an overview of the entire data corpus (Heath et al., 2010). In the next step of analysis, the catalogue from simulations was revisited with a focus on identifying trainees' talk about imperfections and inconsistencies in the simulator environment. In all, 30 episodes on this theme were identified and categorized according to the type of "glitch" discussed. Categories of imperfections and inconsistencies include frozen screens in need of restart (n=7), malfunctioning instruments (n=4), lack of proprioceptive/kinesthetic feedback (n=3), restricted visibility from bridge wings and aft window (n=11) and lack of depth perception (n=5). As a focus of this study on visual expertise, two episodes related to restricted visibility were selected for further analysis. The episodes were transcribed with attention to verbal utterances and the prosody as well as nonverbal behavior such as body positions, gestures, and gaze shifts.

Preliminary findings and scientific significance

In this study, aiming at examining the risks of negative skills transfer when training in a simulate virtual environment, the metaphor of multiple layers of professional skills and the notion of conceptual change serves as starting points to advance our understanding of how the complex professional practice of maritime piloting can be taught and learned in a virtual environment. Our detailed analysis of the talk and bodily conduct of trainees during training, and our close examination of how they handle imperfections and inconsistencies *in situ*, show how ship handling in a simulator environment is a different activity than ship handling on board a seagoing vessel. In the simulator, maritime pilots in training make use of a variety of navigational instruments to compensate for, and to adapt to, the shortcomings of the visual outlook in the simulator. These findings are in line with previous studies that warn for negative skills transfer due to the lack of photorealism in simulated environments (Hontvedt, 2015). However, our findings show how the trainees regularly articulate and conceptualize the differences between simulations and work on board a seagoing vessel in ways that support the development of visual expertise (cf. Lehtinen et al., 2020). Instead of warning for negative skills transfer, we argue that the challenges of training in a virtual environment seem to lead to enriched conceptual, methodological, and technical knowledge and considerations concerning visually demanding and complex tasks.

Today, training in simulators is an integral part of educational programs that prepare students for professions with high standards of safety, in settings such as healthcare, aviation, and maritime navigation. In this study, we have taken seriously the concerns raised with respect to risks of inducing negative skills transfer when making use of simulators in training. Our study contributes with a detailed analysis of simulator-based training as it is practically accomplished in maritime pilot education, advancing our understanding of simulation as a tool for professional learning. As a result, our study shows how and why simulation training and training on board ships mutually support advancing the trainees' visual expertise in their learning trajectory towards mastery of maritime skills. Finally, we argue that the trainee's ability to handle inconsistencies and imperfections in the simulator is closely related to their prior experience of both training contexts. Hence, learning to simulate is essential in professional education that aims to prepare trainees for work in safety critical domains.

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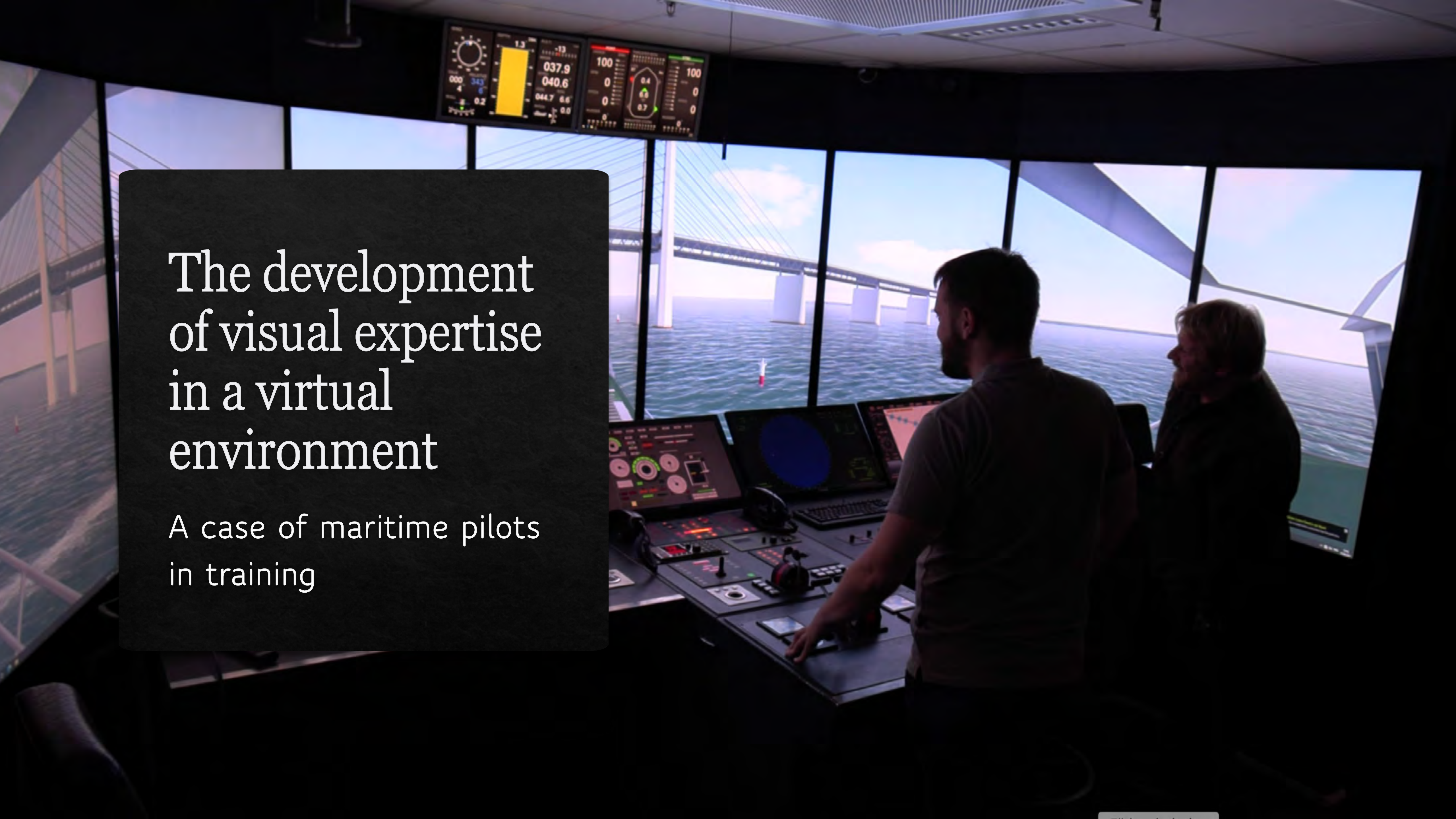
The development of visual expertise in a virtual environment

A case of maritime pilots in training



Problem area

- No matter how technically advanced the simulator is, there will always be "glitches", i.e., imperfections and inconsistencies between the simulator environment and the work context (Rystedt & Sjöblom, 2012)
- Glitches can be seen as a problem, leading to so called "negative skills transfer", i.e. students learning to manipulate the simulator rather than shiphandling (Hontvedt, 2015)
- Glitches can be seen as an instructional resource, i.e., opportunities to discuss the simulation in relation to work practices and work contexts (Hindmarsh et al. 2014; Sellberg, 2017)

Aim and research questions

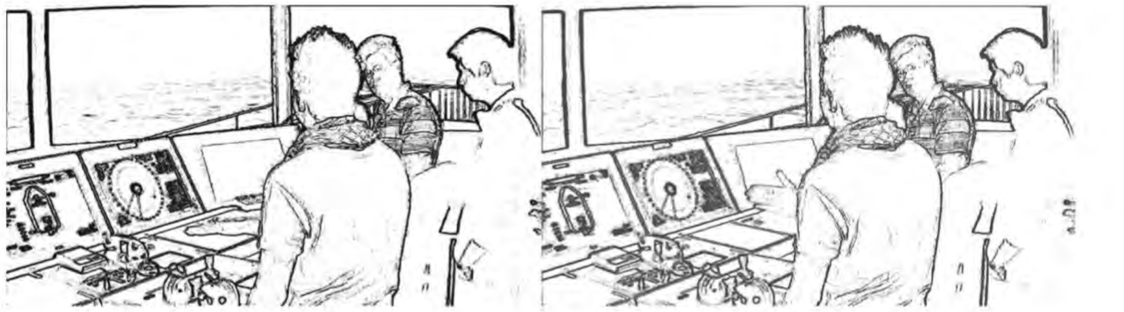
- The aim is to carefully examine the risk of negative skills transfer when training in a simulator environment, directing the analytical focus towards maritime pilot trainees' talk about imperfections and inconsistencies in the virtual environment during exercises in a high-fidelity bridge simulator to answer the following research questions:
  - How do trainees handle imperfections and inconsistencies in the virtual environment during visually demanding tasks?
  - What are the implications of handling imperfections and inconsistencies for the development of visual expertise in maritime pilot training?

Method and analytical approach

- Videography approach (Knoblauch & Schnettler, 2012)
  - Focused ethnography
  - Video-recordings
- Multi-modal interaction analysis (Norris et al., 2012)
  - Verbal utterances
  - Bodily conduct

141126_debriefing_3.1.2 00.15-0.35

STU1: gick de bra?
STU2: thi hi vi kom inte hhhhi ((viker sig dubbel))
STU1: missa ni TSSen?
STU3: ja
STU2: hhhhhhi vi kom inte ens in i TSSen [hhhhi
STU1: [°hhh
STU4: [°hhh
STU2: /ja dö:::r ((kastar sig bakåt))
STU3: alla ba sakta ner
STU2: ja vi ba [wi:u: ((gör en båge med armen))
STU1: [xxx
STU3: [xxx
STU4: de va ni som va akter om oss



Frame 2 Frame 3

Empirical data

- Filming in a course on advanced shiphandling
  - 2 instructors and 6 trainees
  - 4 days of training on 3 bridge simulators
  - Briefing-scenario-debriefing
  - Approximately 130 hours of video recorded training
  - 30 instances of talking about "glitches"

Preliminary results

- Shiphandling in a simulator is a rather different activity than shiphandling a seagoing vessel (cf. Hutchins, 1995)
  - At the *computational level*, the algorithms for of determining distance, speed and turn ratio are the same between conditions
  - Different strategies for gathering visual information (*representational level*)
  - Different strategies for understanding movement, i.e., the details of how the algorithm and representation are realized physically (*implementational level*)

Preliminary results

- Rather than to warn for "negative skills transfer" we want to highlight how the pilots in training are able to articulate and conceptualize the simulation towards the practice on board seagoing ships, showing awareness of the different levels or layers of professional expertise
- Simulation training and training on board are practices that are *mutually advancing* the pilot's expertise in shiphandling in their trajectory towards mastery skills
- We also want to highlight the importance of learning to perform advanced simulations in safety critical professions, training to be prepared for a number of possible events

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RESEARCH REPORT 7

Applied Cognitive Task Analysis (ACTA) of marine piloting in a Swedish Context

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Applied Cognitive Task Analysis (ACTA) of Marine Piloting in a Swedish Context

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ABSTRACT

Modern-day marine pilots are a competent and experienced workforce. They are highly skilled navigators that support the merchant fleet in transiting through challenging sea areas and rivers, as well as in the navigation in and out of ports. In this study, Applied Cognitive Task Analysis (ACTA) was used to pursue a deeper understanding of expertise and tacit or procedural knowledge that experts rely on and exhibit, mostly in safety-critical situations. ACTA is a structured interview method, which relies on three distinct phases: a task diagram, a knowledge audit and a simulation interview. In this article, results from the first two interview steps are presented to show the intricate complexity of pilotage and building blocks of expertise within marine pilotage. A total of eight experienced pilots from two different port areas in Sweden were interviewed. The results show that there are large differences in how pilotage is conducted in the two areas with regards to both tasks, knowledge and understanding of the service as such. Further, despite recognizing maneuvering as cognitively demanding, the pilots emphasized social skills and learning on the job as key elements of expertise. Conclusions drawn from the ACTA structure highlight the mentally and socially complex task that piloting is, and that the pilots use great discernment and acuity when processing verbal and non-verbal input, as well as physical human and vessel movements.

Keywords: Transportation, Maritime human factors, Maritime safety, Cognitive task analysis

INTRODUCTION

Marine pilotage is one of the foremost safety measures within maritime transportation. Marine pilotage is carried out by marine pilots in areas that are challenging to navigate in, such as port approaches or other sensitive sea areas (National Research Council, 1994). Pilots usually are experienced navigators who support the bridge-team of a vessel with their local expertise, and ease the communication flow between shore-based services such as Vessel Traffic Services (VTS), linesmen or tugboats (Darbra *et al.*, 2007). In Sweden, pilotage is offered by the Swedish Maritime Administration, which employs 230 marine pilots who offer nautical expertise and detailed knowledge of local circumstances to ensure a safe and expedient passage in Swedish waters (Swedish Maritime Administration, 2023).

While pilotage's and marine pilots' contribution to safety within maritime operations have been the focus of several studies throughout the past decades (e.g. Darbra *et al.*, 2007; Bruno and Lützhöft, 2009; Lahtinen *et al.*, 2020), only a limited number of studies have explored task design, knowledge and expertise in this domain (e.g. Orlandi, Brooks and Bowles, 2015; Butler, Read and Salmon, 2022). Therefore, little is known about what characterizes expertise and expert knowledge within this domain. This study contributes to the current body of knowledge by utilizing an adapted version of the Applied Cognitive Task Analysis (ACTA) framework (Militello et al., 1997; Militello and Hutton, 1998) to pursue a deeper understanding of what types of cognitive skills marine pilots rely on and exhibit when solving tasks, mostly in safety-critical situations. While, to the best of our knowledge, the application of ACTA within maritime settings has been rare so far (e.g. Brodje *et al.*, 2013), we believe that this structured approach can shed light on the complexity of everyday work and help to identify what characterizes expertise in marine pilotage. Within this article, we will focus only on the results obtained during stages one (task diagram) and two (knowledge audit) of the ACTA, due to limitations of paper length.

METHODOLOGY

This study has utilized an adapted version of the Applied Cognitive Task Analysis (ACTA) framework (Militello et al., 1997; Militello and Hutton, 1998) to explore everyday work of marine pilots. The ACTA method, developed in the late 1990s, can be described as a structured interview approach to identify cognitively demanding aspects of subject matter expert (SME) work within high-risk domains, such as firefighting or nursing. Rooted in the framework of naturalistic decision making (NDM), the method explores critical decisions and the use of information within dynamic environments with the aim to provide input into design and training.

ACTA is split into three data collection stages and one analytical stage. The first stage (task diagram) aims to establish an overall, high-level description of the task at hand; the second (knowledge audit) explores specific sub-tasks that the participant considers particularly mentally demanding, probing specific behaviors that are associated with expertise; the third stage (simulation interview) takes the participant through a simulated task (in this case, maneuvering to berth) in several steps, inquiring about what course of action they would take based on available information, and introducing situations that require intentional decision-making. This last data collection stage was supported in this study by mediating objects (i.e. visual aids such as printed sea charts, visual scene renderings from a simulator, and a model boat) to focus the discussion. The analysis of the structured interview is carried out in the fourth phase, called the Cognitive Demands Table (Militello et al., 1997).

After a pilot interview with an experienced maritime simulator instructor and former pilot was held, the authors found that purely using the ACTA guide as a linear manuscript for probing each stage and situation in turn was quite cumbersome, repetitive and time-consuming. The pilot interviewee also questioned the applicability of some particular probing questions, since most piloting assignments are not standardized in execution. To address these issues, the authors produced a complementary visual template in the form of a matrix on paper for the Knowledge Audit (Figure 1) and the Simulation Interview (Figure 2), to guide the interviewee towards discussing the cognitive skills in question, without requiring them to do so in a linear order.

A total of eight experienced marine pilots were individually interviewed (see Table 1). Four worked at a large industrial and commercial port on Sweden's west coast, area 1 (with container, ro-ro, car, passenger and oil and energy terminals), while the other four worked at a smaller commercial port on the east coast, area 2 (container and ro-ro terminals).

The interviews took between 52 minutes to 1 hour 42 minutes and were audio recorded for Phases 1, 2 and 3, while the third stage (the Simulation Interview) was also video-recorded in a way that only showed the participant's hands from above pointing to the visual mediating objects in the simulation sequence (Figure 3). The interviews were conducted in Swedish,

[Task at hand]		
Aspects of expertise	**a) Cues and strategies** (how is the need discovered?)	**b) Why difficult?** (what can make execution difficult?)
Past and Future (predicting the chain of events)		
Big picture		
Noticing cues and patterns		
Job smarts		
Opportunities/ Improvising		
Self-monitoring		

Figure 1: Visual matrix of the knowledge audit stage (translated from Swedish) used as a mediating object in this study.

Maneuvering to berth				
Steps (events where evaluation or decision-making occurs)	**What do you do?** (Actions)	**What is your judgment of the situation?**	**What clues do you use?**	**Possible mistakes for a less experienced pilot?**

Figure 2: Visual matrix of the simulation interview stage (translated from Swedish) used as a mediating object in this study.

Table 1. Sample information of interviewees.

Location	Gender	Age range	Years of seafaring experience	Years of pilotage experience
Area 1	3M, 1F	41 – 58	10 – 27	4 – 25
Area 2	3M, 1F	43 – 45	10 – 25	1 – 14

Figure 3: Example of video documentation in the simulation interview stage.

as this was the pilots' working language. All interviews were transcribed verbatim, and a consolidation of the data was carried out using the 4th ACTA phase, the Cognitive Demands Table.

ANALYSIS AND RESULTS

In the following sections, the interviewed pilots will be referred to as SMEs (subject matter experts).

Task Diagram: Pilotage in Area 1

Figure 4 presents an overview of the tasks and related aspects of piloting a vessel within area 1. The figure is compiled from the respondents' task diagrams and reflects all tasks and aspects mentioned. There was a large degree of agreement among the area 1 pilots with regards to the mental model of there being three different phases of a pilotage; Preparation, Piloting and Maneuvering to berth.

The preparation phase starts during the transit from port to the vessel. The pilot familiarizes him- or herself with the vessel specifics, checks the current environmental conditions, such as wind and weather forecast, and prepares a passage plan for the voyage. The preparation phase ends in a Master-Pilot Exchange (MPEx) after the pilot has boarded.

During the piloting, which can be seen as the transit into the port area, the pilot and bridge team navigate the vessel jointly. Tools associated with Bridge Resource Management (BRM), such as closed loop communication, are used to maintain situation awareness and enable joint decision making. It is important to maintain a clear distribution of roles among the team members. This distribution is established during the MPEx. During the piloting,

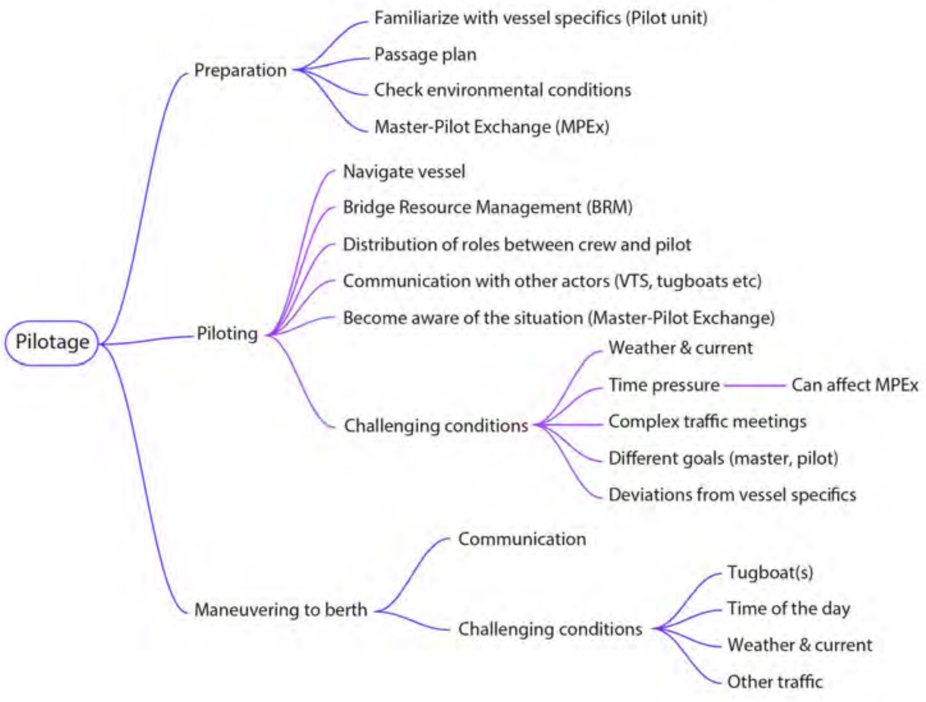

Figure 4: Task overview for pilotage in area 1.

communication among the team onboard and with other actors, such as the VTS, other traffic or potential tugboats, may also take place.

The SMEs emphasize several conditions that may increase the complexity and thus pose a challenge during the piloting phase. These conditions include time pressure, complex traffic meetings, deviations and deficiencies of the vessel being piloted, the state of the crew (in terms of well-being), as well as heavy winds, currents, and weather.

The last phase of the pilotage is the maneuvering from entering the port area to the assigned berth. This phase requires an increased amount of communication both within the bridge team and with other actors, such as the VTS or the linesmen. Several conditions may pose additional challenges, such as the use of tugboats, weather conditions, other traffic in and out of the port, as well as the time of the day.

Task Diagram: Pilotage in Area 2

Pilot area 2 is a larger pilot area with a longer transit period into port. Thus, although the pilotage can be split into the same three phases as pilotage in area 1, the tasks and associated aspects differ (Figure 5).

The preparation phase is started by receiving the pilot assignment through the designated pilot planning system (which pilots can access through a mobile device such as a smartphone). One expert also mentions that they check the planning system regularly, but in the other three cases SMEs identified the assignment as the starting point. Once the assignment is received,

Figure 5: Task overview for pilotage in area 2.

the pilots use their previous experience to categorize the vessel type and its potential requirements and challenges, as well as prepare a voyage plan. If certain facts in the assignment are identified as not possible to adhere to, such as an unrealistic Estimated Time of Arrival (ETA) in port, the pilot also acts as coordinator and communicates with other involved parties, such as the agent in port, the pilot planner, linesmen, and tugboat operator(s) to align the planning. Further, during the preparation phase the passage planning for the pilotage is conducted, and previously made plans are revised and updated based on available facts, such as other expected traffic in the area, destination for the specific vessel, weather, wind and current. One pilot mentions using mental simulation and 'what if'-thinking to explore potential risks and evaluate whether the plan is feasible.

The piloting through the area is characterized by transit navigation through the area, i.e. the bridge team uses mostly an autopilot (with some exceptions including hand steering with the help of a helmsman). The piloting phase is started by making boarding arrangements on the radio and boarding the vessel. After boarding, the MPex takes place during which the role of pilot and master during the pilotage are established, as well as the passage plan and vessel specifics. Like in area 1, communicating with the vessel's crew is seen as an important part of the pilot's work. Establishing a good contact with the bridge team is mentioned as a precondition for successful cooperation during the voyage.

The last phase of the pilotage is the maneuvering to berth, which includes both transit through the port channel, the maneuvering to berth and actual berthing. Since area 2 is a larger area and characterized by a longer transit period, this last phase is initiated through another MPEx to agree upon who will maneuver the vessel to the berth (master or pilot) and agree upon the specific arrangements for the operation.

KNOWLEDGE AUDIT

In the knowledge audit phase, six out of eight pilots identified *maneuvering* as the most cognitively demanding task when conducting a pilotage. One respondent chose to focus on a specific situation dealing with a *machine failure*, and another on the preparation, or *pre-maneuvering*, phase.

Maneuvering is considered cognitively demanding as it requires an intricate mixture of skills that are technical (such as understanding the vessel movements and impacts of weather and currents) and non-technical (such as communication, decision making and establishing leadership in the team) throughout the task execution. The SMEs emphasize the need to be flexible in the light of sudden changes in the operational conditions, and emphasize the complexity of their everyday work, as no pilotage is alike.

Past and Future (Predicting Chain of Events) and Big Picture

Pilots are experienced navigators and have served within the merchant fleet several years before being eligible to join the pilot organization. However, transitioning from a navigator into a pilot role is challenging, as the former is familiar with a specific vessel, while the latter needs to be an expert advisor for a large variety of vessel types in a determined sea area, where every piece of information, such as water depths, buoys, fairways etc. needs to be learned by heart. The SMEs within this study highlight that expertise is built through experience, rather than through being a good navigator. It is important to build a repertoire of vessel types, weather conditions, and social interactions with different crews to be able to quickly adapt to the conditions during a specific pilotage, and to be able to predict potential outcomes, developments and identify risks. Thus, building one's own knowledge and experience base is essential to become an expert pilot, and sets novices and experts apart within the domain.

While pilots go through an extensive training period, the SMEs emphasize that learning on the job is the key, i.e. both during the time as trainee where an experienced pilot acts as advisor and supervisor, as well as continuously during the work where every new situation a pilot faces becomes part of their knowledge base.

Job Smarts, Routines, Planning and Improvising

The SMEs highlight the importance of planning and conceiving several alternate plans as a precondition for being able to adapt and act quickly when the circumstances for the operation change. Planning normally occurs in the preparation phase where generic plans from a pilot's knowledge base are adapted to the anticipated operation. For this, vessel type, weather conditions, flag state and whether a specific vessel has been piloted before are essential indicators for whether a plan need to be changed. Unless the weather conditions are bad, i.e. strong winds or currents, most pilotages are considered routine operations, although with a large complexity in everyday work that requires the pilot to keep in mind many factors beyond their control.

The SMEs had difficulties to name specific job smarts or situations where a need to improvise occurs, mainly because they emphasized that there is always at least one backup plan prepared. Further, job smarts are rather seen as processes and strategies that are learned in the interaction with other pilots. This type of interpersonal and informal learning can be identified as a safety-increasing measure and essential to building expertise.

Cues and Self-Monitoring

The SMEs mentioned visual cues as important for the maneuvering and to determine whether a pilotage is proceeding according to plan, or if changes and adaptions are needed. Visual cues can both be information available in the pilot tablet, the bridge system or in the external environment. Further, verbalizing the passage plan during the MPEx also allows for self-monitoring and monitoring of the bridge team during the pilotage. If an open communication is established, the procedure of the operation can be monitored and challenged by both bridge team and pilot alike.

One of the SMEs specifically stressed that the difference between novices and expert pilots lies in the ability to anticipate deviations and make changes and adjustments ahead of time, while novices, with less experience, are prone to use corrective actions and become reactive, which often affects the quality of the outcome more. Thus, it can be concluded that the ability to self-monitor and regulate is a facet of expertise built through work experience.

Further, despite the emphasis on the maneuvering as being cognitively demanding, this SME reasoned to a large extent about the importance of social interactions and cues provided in the social environment onboard. Social aspects include finding one's role in the bridge team during the operation and establishing a clear communication among the team members to coordinate the work. Maritime resource management (MRM), which is also referred to as Bridge Resource Management (BRM) by the experts, provides tools and a mindset that can help to support the pilot during the work.

It is emphasized that the ability to take on different roles in the team as well as the ability to communicate clearly and establish leadership are important to support the safe conduct of the operation. Roles mentioned by the SMEs range from being a support to the bridge team and mainly monitoring their actions, to actively taking control within the navigation by providing instructions to the helmsman and master. Signs of stress, incomplete communication or mismatches between what is communicated and what is done, can be used as cues to change one's behavior and adapt to the needs to the crew.

DISCUSSION

In comparison to "traditional" studies utilizing ACTA to provide input into training or technology design, this study has tried to explore aspects of expertise in everyday work that involves great adaptability to changing circumstances.

The results show the importance of operational experience and knowledge transfer through interpersonal and informal learning as key components to becoming an expert pilot. Unfortunately, since this type of learning occurs informally, many important lessons might only be shared among a limited group of individuals. It also makes it difficult to draw practical conclusions about how to improve formalized pilot training and education.

While the educational and professional backgrounds as navigator are preconditions, the actual pilotage expertise is built on the job as the individual creates a knowledge and experience base, which can be used to during the preparation phase of a pilotage and enables quick adaptions and the ability to foresee potential needs for corrections.

This study also identified certain difficulties with using the ACTA probes on a type of profession that, for all its planning ahead and protocols, is unpredictable in many micro-perspectives and constantly shifting in response to weather, vessel peculiarities and the state of the crew (in a social sense). In contrast to other professions that have been extensively studied with ACTA before, the safety-criticality of pilotage is not event-based, but rather dependent on constant monitoring and adaptability to shifting conditions. Pilots were sometimes not sure how to fit certain probes to the "right way" to carry out pilotage, nor were they sure whether to call any behaviour a "job smart" or "trick of the trade" as no two pilotage situations are alike, even within the same port.

CONCLUSION

Conclusions drawn from the ACTA's first two stages highlight the mentally and socially complex task that piloting is, and that the pilots use great discernment and acuity when processing verbal as well as non-verbal input, alongside human as well as non-human movements (the latter coming from the vessel and surrounding bodies of air and water).

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RESEARCH REPORT 8

**To sea, or not to sea, that is the question:
Evaluating eye-tracking as a didactical tool and facilitator of tacit knowledge transfer in simulator based maritime pilot training**

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To sea, or not to sea, that is the question: Evaluating eye-tracking as a didactical tool and facilitator of tacit knowledge transfer in simulator based maritime pilot training

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Abstract
Maritime pilots are seasoned mariners providing navigational guidance on specific waterways. This service is based on extensive local knowledge that can be difficult to articulate. Such knowledge can be referred to as tacit. Maritime pilot training is partially performed in maritime simulators where topics can be briefed, trained, and evaluated in a safe, efficient, and economical way. Eye-tracking is a technology where eye-movements can be assessed in different settings such as during training. The objective of this study was to evaluate eye-tracking in simulator based maritime pilot training as a didactic tool as well as facilitator of tacit knowledge transfer. The aim was to assess if eye-tracing can improve the maritime pilot training to comply with increasing requirements of safe, efficient, and environmentally sustainable maritime operations. Based on an explorative mixed-method design, four sub-studies were performed, including fifty-seven participants evaluating eye-tracking in simulator environments. The result showed that eye-tracking can enhance the didactical quality of simulator briefings pre-, mid-, and post-session, as well as enhance the objectivity and the shared perception of events. Eye-tracking also visualized differences in eye-movement strategies between experienced and novice maritime pilots. Eye-tracking did only partially support tacit knowledge transfer since much of the knowledge transfer were explicit or implicit and therefore articulable. Topics such as controlled navigation, ships handling, and hydrodynamics covered most of the training. However, such topics are general skills and not specific pilot skills. Specific pilot skills were however trained partially during non-technical training such as Maritime Resource Management (MRM) but are more prominent during the apprenticeship part of the training. Technical, methodological, physiological, and psychological challenges using eye-tracking need to be further assessed. Furthermore, links between eye-movements, cognitive processes, and learning are not fully clear after this study and require more attention.

Keywords Tacit knowledge · Knowledge transfer · Eye-tracking · Maritime pilot · Maritime training and education (MET) · Pilotage · Maritime simulators

1 Introduction

1.1 Maritime pilotage
Maritime pilotage (hereafter pilotage) is a safety-critical and crucial part of the maritime industry to assure safe, efficient, and sustainable operations at sea. The maritime pilot (hereafter pilot) provides, based on extensive local knowledge, navigational guidance to mariners on specific waterways such as harbors, estuaries, or canals, as well as on the open sea. The pilot interacts with the crew of the piloted vessel, however, with a few exceptions, not as a formal, but an indirect, part of the bridge crew. The pilot provides advisory information in terms of navigation, specific properties of a waterway in terms of depth, obstacles, tides, infrastructure etc. and assists during tugging, birthing, and mooring operations (SMA 2022).

1.2 Pilot training
The Swedish Maritime Administration (SMA) is providing pilotage within Swedish territorial waters as well as a Maritime education and training (MET) in terms of a Pilot Training Program (PTP). Experienced Masters can be selected for pilot training and subsequent employment as pilots. The PTP has a duration of one year and contains three parts: (1) an Introductory course (INTRO), with a duration of 1–3 months, covering employment conditions, safety, regulations, the SMA organization, and general pilotage procedures; (2) a Basic Training for Maritime Pilot course (BASIC) with a duration of 6 weeks, covering maneuvering, navigation, Marine Resource Management (MRM), duties of the governmental officer, boarding operations, hoisting, and hypothermia; (3) a Local Training Plan course (LTP), with a duration of 6–12 months, where the pilot student (hereafter student) participates in between 50 to150 actual missions in cooperation with a senior pilot functioning as supervisor. The LTP concludes with an examination where the student becomes a certified pilot with a basic level Guide note (Level 1). BASIC and LTP is based on International Maritime Organization (IMO) Resolution A.960 (IMO 2010). Post PTP, the SMA provides recurrent training (RECUR) as well as other miscellaneous training and retraining. The RECUR is not a part of the PTP and is run in fixed intervals after the PTP. The PTP is performed in class-room settings, in ship bridge simulator environments, and onboard vessels.

1.3 Maritime simulators

Maritime simulators (hereafter simulator) has been used in various maritime domains such as during offshore and oil rig training (Sellberg 2017), nautical studies (Hensen 1999), navigation and ships handling as well as pilot training (Eklund et al. 2020). Using simulators, scenarios can be specifically set up and adjusted to match required learning outcomes. Simulator training is a valuable instrument for improving maritime safety (Hontvedt and Arnseth 2013), to develop technical as well as non-technical skills (Baldauf et al. 2012), to train and evaluate work practices (Eklund et al. 2020), to develop strategies for e.g. stress-coping, decision making, and communication as well as performing MRM-training (Hontvedt 2022; Saus et al. 2010, 2012). Simulator training furthermore enable training of potentially hazardous tasks in a safe and controlled environment, thus allowing for mistakes and the subsequent learning from them (Passosa et al. 2016; Nazir et al. 2015b). However, Hontvedt and Arnseth (2013) point out that a simulator does not add much per se in terms of learning and that the advantage of using simulator training is related to the process of interacting with other crew members. Furthermore, the impact fidelity, the degree to which a maritime simulator corresponds to the characteristics of the real-world environment, has on learning outcomes has been questioned by e.g. Rystedt and Sjöblom (2012) and Dahlstrom et al. (2009).

1.4 Knowledge transfer and tacit knowledge

Accurate knowledge management is vital for an organization to improve its performance (Nonaka and Takeuchi 1995), stay competitive (Teece 1998), assure productivity (Haldin-Herrgard 2000), and to assure safety-critical operations (Boy and Barnard 2006). However, there is a risk that vital knowledge disappears when experienced individuals leave an organization (Smith 2001). Formalized and codified organizational knowledge referred to as explicit knowledge or know-what (Brown and Duguid 1991) can be located, stored, and communicated within the organization (Wellman 2009). It can however be difficult to describe how a complex working task e.g. is performed. Polanyi (1967) formulated this as '*we can know more than we can tell'*. Such knowledge, referred to as implicit (or tacit) knowledge, develops through practice over extended periods of time and often in social settings. Tacit knowledge is not easily accessible for articulation and can be expressed as skills (Nelson and Winter 1982), as know-how (Kogut and Zander 1992), or as procedural knowledge (Stanley and Williamson 2001). Nickols (2000) points out that tacit knowledge can be communicated and transferred however not articulated. Implicit knowledge and tacit knowledge are often used interchangeably. However, Howard et al. (2009) suggests explicit knowledge as already articulated (books, instructions, animations e.g.), implicit knowledge as articulable but has not yet been (reflections, unrecorded observations e.g.) (see also Nicols 2000), and as tacit knowledge that cannot be articulated (intuition, skill e.g.) (Leonard and Sensiper 1998). Tacit knowledge is moreover difficult to manage in terms of elicitation, documentation, and transfer, on individual as well as on group level (Waefler et al. 2018). Dalkir (2005) pointed out that tacit knowledge is a relative concept since one individual may easily articulate something which may be difficult by another and that the same content may be explicit for one individual and tacit for another. Leonard and Sensiper (1998) suggests that tacit knowledge can be both knowledge that is *"embodied in physical skills resides in the body's muscles, nerves, and reflexes"* (learned by practice) and knowledge *"embodied in cognitive skills is likewise learned through experience and resides in the unconscious or semiconscious"* (learned by experience). However, reflexes are involuntary innate responses to stimulus (Fisher and Truog 2015) while the muscle memory is acquired through repetition over time allowing tasks to be performed without conscious effort (Krakauer and Shadmehr 2006). It has also been argued that the concept of tacit knowledge is under-specified and resists operationalization (Spender 1993; Ambrosine and Bowman 2001). Knowledge conversion theory can be used to better understand tacit knowledge processes but has not been used adequately in higher education and training (Peng et al. 2021). Nonaka and Takeuchi (1995, 1996) introduced the SECI-model (Fig. 1) illustrating how explicit and tacit knowledge is converted into organizational knowledge. Knowledge conversion is described as *socialization* (sharing knowledge via e.g. observation, imitation, and practice), *externalization* (crystalizing knowledge via e.g. dialog, documentation, and articulation), *combination* (integrating knowledge to generate new knowledge via e.g. networks, transversal activities, and exchange), and *internalization* (applying knowledge via e.g. reflection, making sense, learning-by-doing). The SECI-model has however been criticized for its high level of abstraction and uncertain accuracy in terms of empirical grounding (Glisby and Holden 2003; Gourlay 2006) as well as for its inability to explain how new ideas are developed and the notion of collaborative knowledge building (Bereiter 2002).

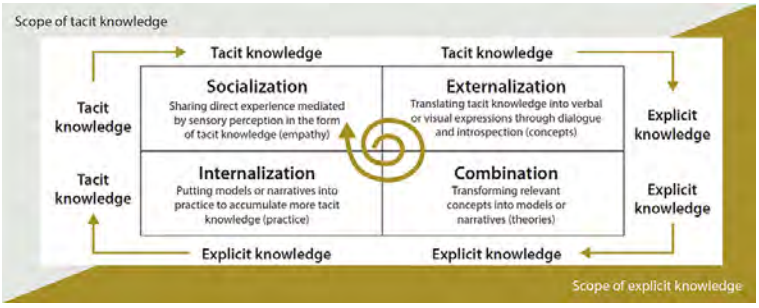

Fig. 1 The SECI-model (Nonaka and Takeuchi 1995, 1996) as described by Hitachi (2023).

1.5 Eye-tracking

For human beings approximately 80% of the sensory information relies on vision (Takvam 2010). Studying eye-movements can be means of gathering sensory information in relation to vision and cognitive processes (Chen et al. 2022). Eye-tracking can be used to evaluate eye-movements in terms of patterns, fixations, and durations by estimating the point of gaze (Nivvedan 2014). By illumination of the pupil with infrared light and recording the reflection that appears on the cornea, information on eye-movements, such as attention maps and scan paths can then be obtained (Holmqvist et al. 2011).

In maritime research, eye-tracking has been used for e.g. evaluating handling of equipment on ship bridges, observing interaction, attention, vigilance, and situational awareness in training and evaluation situations (Wang et al. 2010; Muczyński et al. 2013). Eye-movements have furthermore been used to study expert and novice visual attention where experts display shorter fixation duration, more precise fixations on relevant targets, prolonged saccades (Gegenfurtner et al. 2011; Crespi et al. 2012) and make better use of peripheral vision (Kasarskis et al. 2001). Expert mariners furthermore used navigational aids less, had a larger visual horizon, and allocated more dwell time to environmental cues when driving high speed boats compared to novice mariners (Forsman et al. 2012) but only minor differences in fixation durations were found. Additionally, eye-tracking can be used during pre-, mid-, and post-briefings when training in simulators, where instructors and students can analyze events, behavior, and actions taken (Eklund et al. 2020; Eklund and Osvalder 2022).

Eye-focus cannot exclusively differentiate between an individual cognitively assessing a target or simply looking at it. Posner et al. (1980) suggested that foveal fixations are not necessarily equal to visual attention but be a result of e.g. various cognition or vision factors. Shepherd (1986) suggested that changing visual attention is possible without changing fixation point, but changing fixation point without changing visual attention is not.

Eye-tracking cannot provide data on the vision field but is limited to fixations and movements. Events can however be detected in the peripheral field of vision. Peripheral vision (indirect vison) is challenging to evaluate using eye-tracking due to the small field of view and, due to less acuity, objects lack shape or color in the peripheral area of the eye (Strasburger et al. 2011). The eye is however capable of detecting known forms which may result in active or passive filtering where objects are disregarded due to irrelevance. Understanding why areas are fixated or ignored, and to better understand peripheral vision, eye-tracking can be complemented with e.g. interviews and observations. Fixation duration can indicate cognitive processes (Cooke 2006; Holmqvist et al. 2011) but could also be an indication of target fixation, stress, or contemplation on other tasks. Fixation counts can be means to estimate a participant's persistence to solve a task (Nakayama et al. 2002) but could also be an indication of uncertainness, stress, or random strategies. However, an accurate understanding of the relationship between eye-movements and cognitive functions (Posner et al. 1980; Posner 1980, 2016) or the relationship between eye-movements, training and learning outcome is not clearly established (Mayer 2010).

1.6 Objective

The objective of this study was to assess eye-tracking during simulator-based pilot training as a didactical tool and as a facilitator of tacit knowledge transfer. The goal was to assess if eye-tracking could improve pilot training to comply with increasing requirements of safe, efficient, and environmentally sustainable maritime operations.

1.7 Research questions

Two research questions (RQ) were formulated:

- RQ1: can eye-tracking be used as a didactical tool during pilot training in simulators?
- RQ2: can eye-tracking be used as a tool to improve tacit knowledge transfer between expert and novice pilots during training in simulators?

2 Method

2.1 Demarcations

Explicit, implicit, and tacit knowledge were used with the following meanings (Nickols 2000): explicit knowledge (articulable), implicit knowledge (articulable but not yet articulated), and tacit knowledge (not articulable or very difficult to articulate). Research instruments such as questionnaires and interviews may be inefficient when assessing tacit knowledge and are likely to be "*inappropriate insofar as individuals cannot be asked to state what they cannot readily articulate*" (Ambrosini and Bowman 2001). Using questionnaires to study tacit knowledge were therefore omitted. Nonetheless, it was assessed that interviews could be a supplement to establish triangulation. No document analyses were performed on eye-tracking since the SMA did not use such didactical support.

2.2 Study design

This study is a *compilation* of four studies (Study 1–4). An exploratory mixed method design approach (Greene et al. 1989; Creswell et al. 2003), including 57 participants, was used to evaluate eye-tracking as a didactical tool as well as eye-tracking to study tacit knowledge and tacit knowledge transfer during the PTP.

Study 1 (n=19) was deployed during a BASIC course and *Study 2* (n=6) was deployed at a RECUR course. Data were collected from a mix of questionnaires, semi-structured interviews, observations, and document analyses on (1) the usability of using eye-tracking in simulator training and (2) to assess if eye-tracking could improve the PTP in terms of locating, catching, documenting, and transferring tacit knowledge. Simulator ship handling scenarios from the PTP curriculum were used in Study 1 and 2 (Table 1).

Study 3 (n=19) was deployed at a BASIC course. Initially, a focus group interview was performed with four instructors to enhance the understanding of instructors' experiences, needs, and solutions to common didactical challenges. The results were fed back into Study 3 and 4. Data were collected from a mix of questionnaires, semi-structured interviews, observations, and document analyses on (1) the usability of eye-tracking as a didactical tool in simulator training and (2) if eye-tracking could improve the PTP in terms of locating, catching, documenting, and transferring tacit knowledge. Simulator ship handling scenarios from the PTP curriculum as well as customized scenarios were used in Study 3 (Table 1).

Study 4 (n=13) was deployed at a customized concluding FINAL assessment. Data were collected from a mix of questionnaires, semi-structured interviews, observations, and document analyses on (1) the usability of eye-tracking as a didactical tool in simulator training and (2) if eye-tracking could improve the PTP in terms of locating, catching, documenting, and transferring tacit knowledge. Simulator ship handling scenarios from the PTP curriculum as well as customized scenarios were used in Study 4 as well as experiences from Study 1–3 (Table 1).

Table 1 Compilation of simulator scenarios for Study 1–4.

Study nr		1	2	3	4
Event		BASIC	RECUR	BASIC	FINAL
Simulator nr		SIM1/2	SIM1/2	SIM2	SIM1/2
Participants total		19	6	19	13
Participants in each crew		3[a]	3[a]	2[b]	3[c]
Scenario[d]	Duration, minutes	Run, amount	Run, amount	Run, amount	Run, amount
1 Approach, 180° turn, small basin, birthing	45	7	-	-	-
2 Approach, tug support, 90° turn, birthing	44	-	4	-	-
3 Contingency anchor, confined waterway	20	-	-	2	-
4 Departure, confined waterway, traffic situation	25	-	-	2	-
5 Approach, 90° turn, small basin, birthing	20	-	-	2	-
6 Approach, tug support, birthing	22	-	-	1	-
7 Under way, turns, confined waterway	20	-	-	1	-
8 Departure, 180° turn, small basin	15	-	-	9	-
9 Under way, overtaking, confined waterway	21	-	-	3	-
10 Approach, small basin, tug support, birthing	22	-	-	1	-
11 Approach, confined waterway (LTP[e])	15	-	-	-	1
12 180° turn, small basin, birthing (SH[e])	15	-	-	-	2
13 Approach, confined basin, birthing (PT[e])	17	-	-	-	2
14 Departure, confined waterway (MRM[e])	16	-	-	-	2
Total	894	7	4	21	7

[a] Each crew consisted of one student acting as pilot, one student acting as Master and one student as observer.
[b] Each crew consisted of one instructor as Master and one instructor as observer.
[c] Each crew consisted of one instructor acting as pilot and one instructor acting as Master.
[d] Scenario 1–14 performed in daylight, good meteorological visibility, light variable wind, and no current.
[e] LTP=Local Training Plan, SH=Ships Handling, PT=Pilot Test evaluation, MRM=Maritime Resource Management.

2.3 Procedure

Studies 1–4 were performed in simulators as well as class-room settings at the SMA combined research and innovation (R&I), and simulator facility in Gothenburg, Sweden according to a systematic research procedure (Figure 2). Data were collected by questionnaires, interviews, observations, and document analysis during the study. Data analyses were performed by thematic inductive analyses as well as descriptive statistical analyses.

A literature study was performed initially to establish an understanding of the research fields. RQ1 was conceptualized into *training* and RQ2 into *transfer of knowledge*. These concepts required however a higher level of abstraction due to challenges of observing a multi-dimensional phenomenon and were therefore enhanced into constructs. Training was enhanced into *learning* since training was assessed as contain more activities outside the mind of the individual and *"…is characterized as an instructor-led, content-based intervention leading to desired changes in behavior*" (Truelove 1992) compared to learning that was assessed as containing more activities inside the mind and is "*an ongoing process that lies in the domain of the individual*" (Sloman 2005). Transfer was consequently enhanced into *reproduction of skills* since transfer alone was assessed being limited to only conveying information and not the reproduction of skills. The constructs were thereafter operationalized using four simulator studies (Study 1–4).

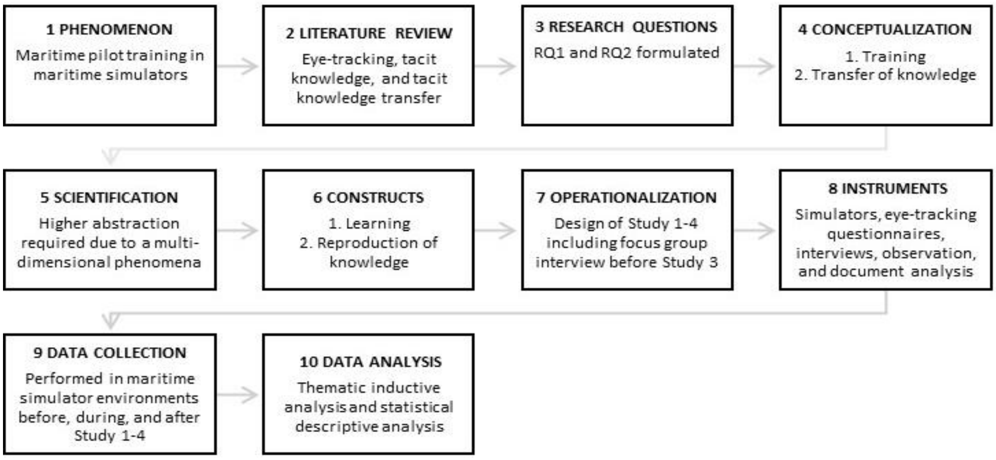

Fig. 2 Description of the research procedure.

Prior to Study 3 a focus group interview was performed with four instructors to enhance the understanding of instructors' experiences, needs, and solutions to common didactical challenges. A thematic inductive analyze (Braun and Clarke 2006) (Table 2) based on the focus group interview was used. Answers were examined, categorized, and interpreted to elicit further meaning and understanding using a thematic inductive analyze to identify themes. resulted in four didactical areas of interest (Situational awareness, Didactical feedback, Data and information retrieval, and Shared understanding of events) which were subsequently implemented in Study 3 and 4.

A pre-session check was performed in the simulator before each study to have the staff at the facility accustomed to the eye-tracking equipment and to mitigate practical and technical complications. A 15-minute pre-session familiarization was deployed before each simulator session, to accommodate the participants to the eye-tracking equipment and to the simulators. Before each study was performed, a pre-study briefing was distributed by e-mail to the participants, presenting the objective of the study. This information was also repeated verbally arriving at location. Each simulator session was documented by an instructor in a specific schedule including designation, purpose, design, location, meteorological conditions, time of day, vessel type, participants, and remarks from the session. Video and audio recordings were analyzed post-session.

Table 2 Examples from the thematic inductive analyze procedure, adapted from Braun and Clarke (2006), applied during Study 3 and 4.

Transcriptions from focus group interviews with PTP instructors	Coding	Themes	Simulator session
"I find it challenging to see where students are looking on the bridge during simulator sessions, it will be subjective from my side. If I could understand eye-patterns they use to gather information from instruments [on the ships bridge] *I could see if they divide too much or too little attention at things"*	Assessing student eye-focus to assure directing attention at the optimal area of the ship bridge at that time. Student is gathering relevant data and information matching current and expected conditions.	Situational awareness, Feedback. Data and information retrieval.	1–14 1–14
"During the LTP, maybe we could show a filmed approach or something like that and then I could read aloud from my notes or from memory important things, beacons, bearings, local things at a briefing before the simulator"	Assuring that the student and the instructor have a shared understanding of events. Student is gathering relevant data and information matching current and expected conditions.	Shared understanding of events Data and information retrieval.	11
'The instructor that followed the live-stream and the student had the same picture of where the student eye-focus was. This common picture is very useful during briefings and de-briefings I believe"	Assuring that the student and the instructor have a shared understanding of events.	Shared understanding of events.	1–14
"[The] *result is so clear, and if you want you can map eye-patterns and you can teach good ones also. You can instantly see what they are doing and looking at and in the moment if possible hint or guide them and then wait for the result. Students making the same mistakes over time, we can detect those mistakes and correct them"*	Instructors can after a given instruction, advice, or guidance receive a confirmation on actions taken.	Didactical feedback	1–14

2.4 Participants

For Study 1–4, in total 57 participants (Tables 3 and 4) were recruited on a voluntary basis by the SMA R&I from different parts of the pilot training, either as pilots, instructors, or students. All participants were seasoned mariners and had worked as commanders on merchant vessels. Each participant was informed about the background and objective of the study. Following a confirmation of informed consent all participants were informed that they could cancel their participation at any time.

Table 3 Characteristics of participants in Study 1–4 in terms of age, gender, and years at sea.

	Total		Male		Female	
Total, N	57		54		3	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age, years	46.7	6.5	47.3	6.3	40.3	7.6
Years at sea[a]	23.5	8.3	24.1	8.3	18.7	6.8
Line of work[b]						
	N	*%*	*N*	*%*	*N*	*%*
Master[c]	45	100	41	91	3	9
Pilot	21	47	17	38	2	9
Instructor	28	62	26	58	2	9
Student	19	42	19	42	1	0
R&I	6	13	6	13	0	0

Table 4 Distribution of occupancies, frequencies, and percentages for participants in Study 1–4.

	Study 1		Study 2		Study 3		Study 4	
Total, n	19		6		19		13	
Line of work[b]								
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Master [c]	19	100	6	100	19	100	13	100
Pilot	6	37	6	100	11	58	12	92
Instructor	4	21	2	33	6	32	13	100
Student	12	63	0	0	5	26	0	0
R&I	2	11	1	17	2	11	2	15

[a] Year at sea includes all types of duty.
[b] Total greater than 100 % as more than one line of work is possible.
[c] In this study the concept of Master includes as minimum the level of a licensed Mariner certified to function as commander of a merchant vessel and up to the level of Master Mariner.

2.5 Instruments

2.5.1 Simulators and Instructor station

Two fixed-base full mission Wärtsilä ship bridge center console simulators (Fig. 3) were used in the study. The simulators (SIM 1 and SIM 2) had a generic layout with Navi-Trainer Professional 5000 (Wärtsilä) software. Conning-systems (Wärtsilä) were integrated in both simulators. The Electronic Chart Display and Information (ECDIS) system was a Navi-Sailor (Wärtsilä) with a TX97 navigational database. The Radar systems were BridgeMaster E (Sperry Marine). The VHF-radios were RT5022 VHF DSC (Sailor) set to channels 71–74. The ship bridge interfaces (Lillas) included tillers for steering, propulsion and additional interfaces were fully integrated. SIM 1 had eight 42 inch LCD screens for a 180° outside view and three 20 inch LCD screens for system information. Sim 2 had nine 42 inch LCD screens for 180° outside view and five 20 inch LCD screens for system information. The simulators had one 42 inch LCD screen for aft outside view. Instructors had live visual and audio feedback from the ship bridge from 90° cameras (Axis) including zoom, movement, and recording. The simulators were equipped with a microphone and two speakers each. Instructors and ship bridge crew interacted using VHF-radios as a primary means of communication. The VHF-radio channels had slightly skewed frequencies not to interfere with hot VHF-radio transmissions outside the R&I facility. The simulators were managed from the instructor station in an adjacent room (Fig. 4). From the instructor station parameters such as scenarios, vessel characteristics, location, weather, time of day, currents, traffic, navigation, and communication were managed. The station was always staffed by at least one instructor and had five 20 inch LCD screens showing radar, conning, and ECDIS information as well as outside views and two 42 inch LCD screens showing live eye-tracking streams. One VHF-radio and one loudspeaker for each simulator enabled double way communication. The instructor station contained interfaces to program, control, supervise, monitor, and record events. For briefing purposes, a 100 inch whiteboard with two projectors displayed the simulators live, and/or recorded ship movements on an ECDIS overlay.

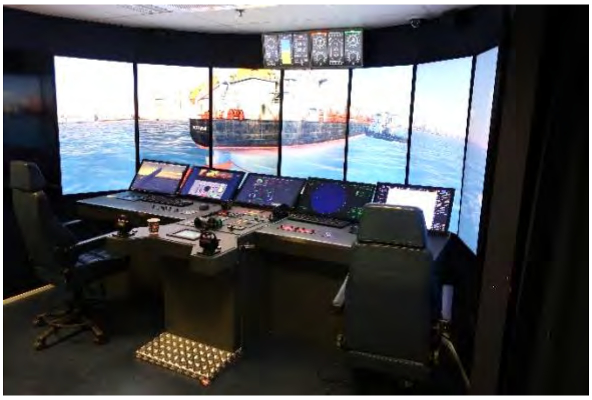

Fig. 3 SIM 1.

Fig. 4 The instructor station.

2.5.3 Eye-tracking system

In Study 1 and 2 a Tobii Pro Glasses 2 (Head unit version 0.0.62) wearable eye-tracking system was used (Fig. 5). The system consisted of glasses including one 90° angle of vison HD scene camera (Field of view: 82° H and 52° V), eight IR illuminators per eye, two eye-tacking sensors per eye, and one microphone. The sampling rates were 50/100 Hz. The glasses were connected to a portable recording unit, carried by the participant, including a battery pack and wireless and HDMI-cables for connection apparatus. The glasses were also calibrated, for optimum accuracy, for each participant in terms of pupil location in relation to the cornea and fovea. The software was Tobii Pro Lab (Version 1.49–1.194) and Tobii 2 Glasses Controller (Version 1.2.5.6) used to record, store, and analyze data. In Studies 3 and 4 a Tobii Pro Glasses 3 (Head unit version 1.28.1) wearable eye-tracking system was used (Fig. 6). This system differed from the Tobii Pro Glasses 2 by having four eye-tacking sensors per eye, a 106° angle of vison HD scene camera (Field of view: 92° H and 63° V). The software used in Study 3 and 4 was Tobii Pro Lab (Version 1.145–1.207) and Glasses 3 (Version 1.13.3).

Fig. 5 Tobii Pro Glasses 2.

Fig. 6 Tobii Pro Glasses 3.

2.5.4 Eye-tracking metrics

Data collection based on Holmqvist et al. (2011) included (1) *fixations*, indicating eye-focus with very small movements on a target measured in position and time, (2) *saccades* and smooth pursuit which are eye-movements between fixations, (3) *attention maps* (heat maps) showing the spatial distribution of fixations without order and displayed in different colors reflecting the number of fixations, (4) *scan path maps* (gaze plots) showing linear eye-movement tracks (saccades), in order, between fixations and the amount of time spent at each fixation displayed as circles of different size, and (5) *dwells*, which are similar to fixations but has its own duration, starting and ending point, and patterns and are in general larger in space and time. Only voluntary eye-movements (saccades and smooth pursuit) were studied and not involuntary (tremor, micro saccades, and drift). The wearable eye-tracking glasses recorded data which were presented as a video file (.wmv), a text file (.txt), or in tables.

2.5.5 Questionnaires

To collect general user experiences from eye-tracking in Study 1 and 2 a five variable (General usability, Didactical usability, Situational awareness, Stress, and Workload) five-point Likert scale (1 Strongly Disagree – 5 Strongly Agree) questionnaire was used. To collect eye-tracking specific user experiences in Study 3 a four variable (Live-streams, Heat maps, gaze plots, and Heat maps combined with briefing) five-point Likert scale (1 Strongly Disagree – 5 Strongly Agree) questionnaire was used. To collect specific didactical user experiences from eye-tracking in Study 4 a five variable (Usability didactical during LTP, Usability didactical during SH, Usability didactical during PT, Usability didactical during MRM, and Usability didactical during PTP) five-point (1 Strongly Disagree – 5 Strongly Agree) questionnaire was used. Usability didactical during the PTP comprised the overall usage of eye-tracking all methodologies combined (live-stream, heat maps, gaze plots, and heat maps & briefings). The questionnaires were distributed in paper form after each simulator session. Information on participant background data such as age, experience, and certificates were also collected in these questionnaires.

2.5.6 Interviews

Semi-structured interviews (Edwards and Hollands 2013) were performed to gather data on (1) on eye-tracking and (2) on tacit knowledge and tacit knowledge transfer. Interviews were held individually with 14 instructors and 35 students and contained two themes: Theme 1 (Eye-tracking, 15 questions) and Theme 2 (Knowledge and knowledge transfer, 15 questions) as well as background questions (Table 5). These interviews were recorded electronically, transcribed, and subsequently used for triangulation in the study to enhance collected data.

Table 5 Examples of semi-structured interview questions, for instructors and students, during Study 1–4.

Themes	Participant	Section	Question
1 Eye-tracking	Student	1.3 Didactical support	1.3.5 Please state if eye-tracking supported you reaching intended learning outcomes and if so, how?
1 Eye-tracking	Instructor	1.4 Challenges	1.4.1 Please describe challenges, if any, you encountered using eye-tracking.
2 Knowledge and knowledge transfer	Student	2.3 Didactical support	2.3.2 Please describe which written course material such as books or handouts you think were useful to you.
2 Knowledge and knowledge transfer	Instructor	2.4 Learning	2.4.2 Please describe your preferred method to brief students after simulator sessions.

2.5.7 Document analysis

A document analyses adapted from Rapley (2007) and Krippendorff (2004) were performed using 63 written documents (paper and/or electronic) retrieved from the SMA intranet and on site during the BASIC courses including curriculums, course literature, and operating procedure descriptions. All documents were read in full and screened using the following terms: *tacit*, *implicit*, *skill*, and *procedural* as well as emerging terms with adjacent meanings to identify established descriptions of methods for transferring tacit knowledge. Furthermore, the document analysis was performed as a means of triangulation to increase the validity of the study (Pettigrew 1973).

2.5.8 Observations

Passive participant observations (Musante and DeWalt 2010) during Studies 1–4 was performed at the SMA R&I and simulator facility in classrooms and during simulator training as well as during briefing before, during, and after simulator sessions. These observations were performed to assess eye-tracking usability as well as tacit knowledge transfer and were documented in protocols including field notes (Bogdan and Biklen 1992) as well as using audio- and video-recordings. Observations were examined, categorized, and interpreted to elicit further meaning and understanding using a thematic inductive analyze (Braun and Clarke 2006).

2.5.9 Data analysis

Data on participants were analyzed by mean values and standard deviations for continuous data (age, years at sea) and frequencies and percentages for categorical data (gender, line of work). Self-assessments from eye-tracking usability studies were analyzed in terms of mean values. Voice recordings from interviews were analyzed in terms of edited verbatim transcripts and organized by using a thematic inductive analyze (Braun and Clarke, 2006). Live video transmissions from the simulator sessions were analyzed by observation and simultaneously noting events of interest in an observation log. The same procedure was applied during post-session video recordings where the participants, in an informal way, furthermore, could reflect on these video recordings. Eye-tracking data was analyzed by using software post-session programs, as well as by observing live streams from the eye-tracking glasses. Two variables with negative implications (Stress and Workload) where in the subsequent statistical analysis reversed not to alter the sequence of wording in the question statements.

3 Results

The results are reported as a *compilation* of results from Study 1–4. These studies were performed on simulator ship bridges, in classrooms, and during training breaks, meals, or other informal occasions. In Section 3.1 are results from eye-tracking usability assessments based on questionnaires (response rate 86%) and interviews (in total 41) presented. In Section 3.3 are results from tacit knowledge transfer assessments based on observations (in total 129 hours with 55 hours during simulator sessions, 65 hours in class-room settings, and 9 hours in miscellaneous environments), interviews (in 14 total), and document analysis presented.

3.1 Usability of eye-tracking

3.1.1 Study 1 and 2

Study 1 (BASIC) showed similar, but lower, self-assessment mean values on all five variables compared to Study 2 (RECUR) (Fig. 7 and Table 6). Usability general showed a lower mean value: technical and operational challenges were experienced in Study 1 and 2 but were more frequent in Study 1. These challenges included live-stream link quality issues between the eye-tracking glasses and the instructor station. Furthermore, the eye-tracking glasses showed not to be suitable for all participants. Wearing glasses, normal as well as reading glasses, and/or contact lenses posed a problem since incorrect eye-focus was generated. Difficulties maintaining the required head posture and not gazing down below the eye-tracking glasses were reported in both Study 1 and 2 as well as increased stress, increased workload levels, and decreased situational awareness were reported when wearing the eye-tracking glasses. A trial run, before each study, to accustom the participants to the eye-tracking glasses was therefore introduced to mitigate these problems. As a result, Stress, Workload, and Situational awareness mean values improved in both studies. Also, a common reaction was *"a stressful feeling of knowing that several other people were watching your actions on a screen in another room"* as one student expressed it. Usability didactical and Workload showed the highest mean values in both studies. Instructors (4 out of 4, 4/4) and students (11/12) in Study 1 and instructors (2/2) and pilots (6/6) in Study 2 reported that learning could be enhanced using eye-tracking. However, using eye-tracking as a stand-alone support to catch and document tacit knowledge was difficult. During a post-session simulator briefing an instructor was asked to describe a specific action (and the decision behind). The instructor stated that *"I did it without thinking, like a gut feeling, difficult to explain"*. In this situation eye-tracking *combined* with briefings were means for discussing events that may be categorized as tacit knowledge. Instructors (5/6) in Study 1 and 2 furthermore reported that their workload, since they did not have to worry about remembering correctly what had taken place during simulator sessions, decreased. Instructors (4/6), students (10/12), and pilots (6/6) in Study 1 and 2 reported that subjective assessments of students' visual attention (fixation, saccades, spatial distribution of fixations, scan paths, and dwells) became more objective using eye-tracking. Instructors, pilots, and students expressed this in terms of establishing a common view of events. Workload was reported by all instructors to decrease since events could be assessed post-session. One instructor stated that *"now I can focus on the training instead of making notes all the time"*.

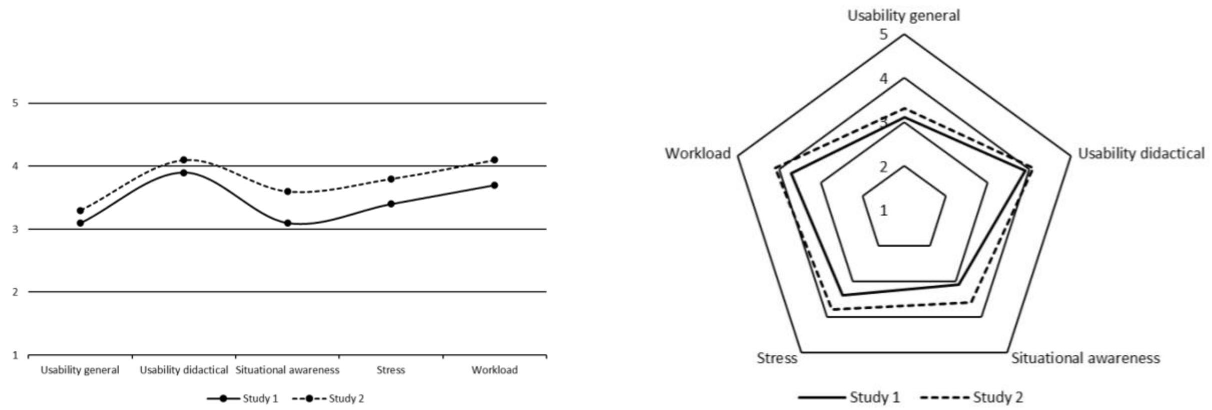

Fig. 7 Study 1 (BASIC) and Study 2 (RECUR) self-assessment mean values from using eye-tracking in terms of Usability general, Usability didactical, Situational awareness, Stress, and Workload.

3.1.2 Study 3

In Study 3 (BASIC) Live-streams, Heat maps and Heat maps & briefings showed higher self-assessments mean values compared to Gaze plots (Fig. 8 and Table 6). Live streams (Fig. 9) were reported by instructors (6/6) as useful for assessing visual attention (fixations and saccades) during different segments of a route but required at constant instructor watch in live situations. Live-streams (real time and videos) were also reported as valuable by many instructors (5/6) and students (5/5) as basis for post-session analysis and to assure a common understanding of events. Live streams (data), however, required substantial resources in terms of time and staffing. Heat maps were reported by instructors (6/6) and students (5/5) as useful to visualize attention patterns and fixation times thereby indirectly inferring cognitive strategies. However, as one instructor pointed out, *"heat maps also display where students are not looking"*. A triangle shaped scanning pattern was observed and documented. In confined areas such as maneuvering in a small basin the triangle consisted of bow-conning-ECDIS (Fig. 10) and radar-bow-conning (Fig. 11 and Table 6) under way. Thus, students adapted their scanning pattern to match a given situation. However, as was pointed out by two instructors, it was difficult to establish if eye-focus was e.g., on the whole radar screen or sections of the screen. Some students (5/6) allocated more attention to navigational instruments such as ECDIS, radar, and coning as well as focusing closer to the ships bridge compared to instructors. Furthermore, heat maps did not provide any information on temporal order of fixations but provided information on how visual attention was allocated in different situations. Gaze plots (Fig. 12) showed the lowest mean values. Instructors (6/6) and students (4/5) reported that gaze plots *were* useful per se but very quickly became too cluttered to make sense. Combining heat maps and briefings were reported as valuable by both instructors (6/6) and students (5/5) since briefings in groups offered a diversity of perspectives, ideas, and solutions. Experiences were shared in a communal environment. One student reported that *"now we can see where I´m looking, Myself and the others* [instructors and fellow students] *as well"*. All instructors reported that heat maps combined with briefings showed the advantages of using eye-tracking expressed in didactical terms.

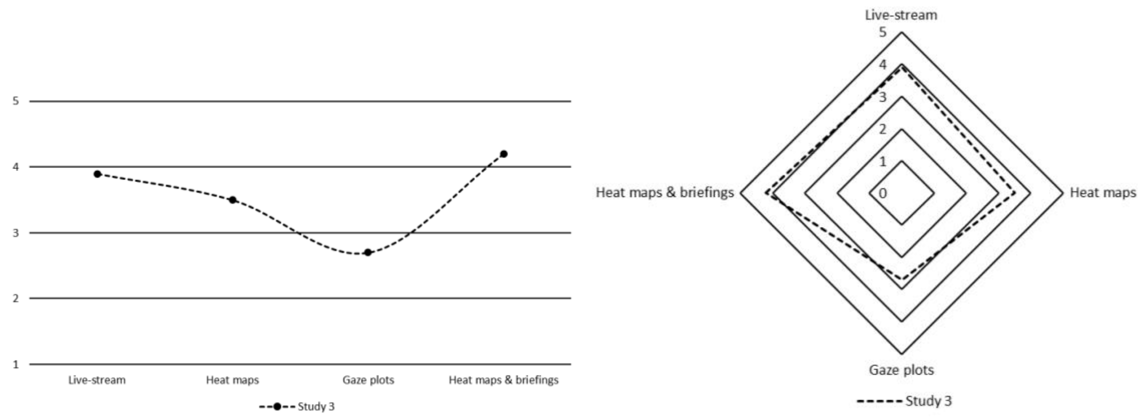

Fig. 8 Study 3 **(BASIC)** self-assessment mean values from using eye-tracking in terms of Usability didactical during Live-stream, Heat maps, Gaze plots, and Heat maps & briefings.

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 9 Example of a snapshot from a video based on live streaming from a Study 3 post-session data analysis departure from a small basin. The red dot shows real time fixation and the red line show saccade movements. Photo approved for publishing by the Swedish Maritime Administration.

Fig. 10 Example of an attention map (heat map) display after Study 3 post-session data analysis from navigation under way. Red color indicates most attention in terms of time and green least attention. Fixation is concentrated to a triangle consisting of bow, conning and radar. Photo approved for publishing by the Swedish Maritime Administration.

Fig. 11 Example of an attention map (heat map) display after Study 3 post-session data analysis from turn in small basin. Red color indicates most attention in terms of time and green least attention. Fixation is concentrated to a triangle consisting of bow, conning, and ECDIS. Photo approved for publishing by the Swedish Maritime Administration.

Fig. 12 Example of a scan path map (gaze plot) display after Study 3 post-session data analysis from turn in small basin. Gazes are numbered to indicate temporal order, fixation, and duration of fixation in terms of circle size. Lines between fixations are displaying saccades in temporal order. Photo approved for publishing by the Swedish Maritime Administration.

3.1.3 Study 4

In Study 4 (FINAL) Usability didactical was assessed including Local Training Plan (LTP), Ships Handling (SH), Pilot Test evaluation (PT), Marine Resource Management (MRM), and Pilot Training Program (PTP) events (Fig. 13 and Table 6). Usability didactical for the LTP, SH, MRM, and PT had lower mean values compared to the PTP. However, LTP, SH, and MRM are included in the PTP as well as during recurrent training. All instructors (13/13) stated that, during the LTP, eye-tracking could be a valuable support. One instructor expressed that *"I can use eye-tracking to make a video-based log which we can use to enhance student awareness of a specific route or procedure, they can see where I am looking"* further stating that *"this will not remove the supervisor but complement them"*. Another instructor suggested that such videos in combination with oral briefings from a given route were valuable and could be compiled into an electronic version of the student´s course booklet (a personal log/diary developed during the LTP on the specific route). Such an electronic course booklet was believed to improve learning as such but was also suggested to be a mean to convey tacit knowledge from experienced pilots. In this case eye-tracking was suggested to visualize behavior The same instructor, however, pointed out that the mere process of creating the course booklet was *"important for enabling learning, a value in itself"*. SH is a common denominator for pilot training and evaluation. However, some instructors (5/13) had the opinion that ships handling during basic pilot training (less experienced students) differ from ships handling during recurrent training (more experienced pilots) since skill was sometimes lower in the first case. During SH many instructors (11/13) believed eye-tracking was useful to catch situations that could easily be missed otherwise. More experienced pilots looked for clues from the ships *behavior* (turn rate, pivot point, bank e.g.) rather than confirming with tiller or throttle position, gauges, indicators, screens, or other interfaces. Experienced pilot´s seemingly effortless interaction with the bridge could be a sign of embodied tacit knowledge. How eye-tracking was to be utilized to convey such knowledge was however not clear. One instructor stated that *"…handling a ship in the simulator is different from the reality*". PT showed the lowest mean values and several instructors (9/13) reported that eye-tracking was not an optimal support during tests and evaluations since it could increase the already high level of stress. Furthermore, as one instructor pointed out, in a PT-environment individuals coping well with eye-tracking induced stress may not necessarily be suitable pilot candidates and vice versa. When asked to elaborate further on which abilities a suitable candidate should demonstrate in test and evaluation situations one instructor stated that *"we are looking for stress tolerant individuals that can handle an unknown ship, but we are in fact mostly looking for communication skills, to interact with a new bridge crew every time they enter the* [ships] *bridge"*. During MRM, eye-tracking was reported having a lower didactical value since the MRM-training is focusing on non-technical skills. Some instructors (8/13) pointed out that MRM-training is more about communication and interaction on individual or group level; events that are *"difficult, or impossible, to assess using eye-tracking"* according to one instructor. *"Eye-focus seems irrelevant in MRM-situations, but you can film the entire crew and watch and listen instead, much more interesting to use during briefings"* according to another. During the MRM two pairs of eye-tracking glasses were also intermittently simultaneously used but none of the instructors reported a didactical value with such usage. "*It became confusing and somewhat comical when we looked at each other wearing our glasses, the data analyze was also overwhelming*" according to one instructor. The PTP showed a maximum mean value. All instructors reported that eye-tracking could be an *overall* useful didactical support during the PTP. Many instructors (11/13) furthermore reported that some segments of the PTP were suitable for eye-tracking usage, but some were not.

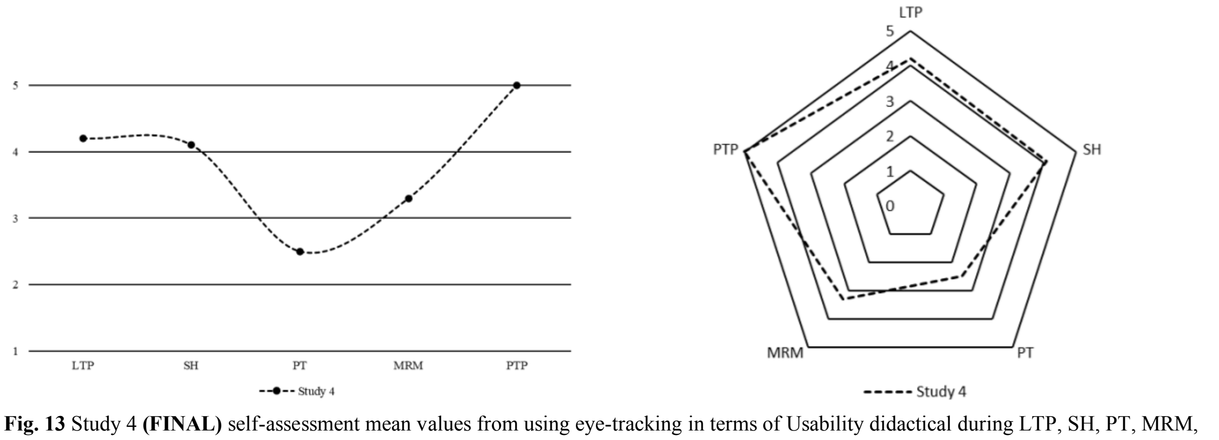

Fig. 13 Study 4 **(FINAL)** self-assessment mean values from using eye-tracking in terms of Usability didactical during LTP, SH, PT, MRM, and PTP.

Table 6. Summary of self-assessments based on five-point Likert scale questionnaires for Study 1–4.

	Study 1 (n=19)		Study 2 (n=6)		Study 3 (n=9)		Study 4 (n=13)	
Self-assessment variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
1. Usability general	3.1	0.7	3.3	0.6	-	-	-	-
2. Usability didactical	3.9	0.9	4.1	0.7	-	-	-	-
3. Situational awareness	3.1	0.6	3.6	1	-	-	-	-
4. Stress	3.4	0.8	3.8	0.7	-	-	-	-
5. Workload	3.7	0.7	4.1	0.7	-	-	-	-
1. Live-stream	-	-	-	-	3.9	0.8	-	-
2. Heat maps	-	-	-	-	3.5	0.8	-	-
3. Gaze plots	-	-	-	-	2.7	0.6	-	-
4. Heat map combined with briefing	-	-	-	-	4.2	0.5	-	-
1. Usability didactical during LTP[a]	-	-	-	-	-	-	4.2	0.4
2. Usability didactical during SH[a]	-	-	-	-	-	-	4.1	0.5
3. Usability didactical during PT[a]	-	-	-	-	-	-	2.5	0.7
4. Usability didactical during MRM[a]	-	-	-	-	-	-	3.3	0.8
5. Usability didactical during PTP[a,b]	-	-	-	-	-	-	5	0

[a] LTP=Local Training Plan, SH=Ships Handling, PT=Pilot Test evaluation, MRM=Maritime Resource Management, and PTP=Pilot Training Program.
[b] Usability didactical for the PTP is a compilation of using eye-tracking in general as a didactical support.

3.2 Tacit knowledge transfer

3.2.1 Study 1–4

Observations and interviews

Students were exposed to knowledge in explicit, implicit, and tacit form. Briefings before, during, or after simulator sessions were focal occasions for sharing knowledge. An essential didactical function of the simulator was to visualize tactics in terms of maneuvers and other actions. The pre-session briefing could either contain analyses and discussions on the previous session and/or prepare the students for the next session. Briefings during sessions were important when significant challenges had arisen and there was a need to intervene didactically (show or discuss). Post-session briefings were important occasions for analysis and reflections as well as preparation for the next session. All observed sessions included elements of ships handling where students rotated positions, thus learning from each other. One student stated that *"I can see what they* [fellow students in the simulator] *are doing, how they resolve situations, even if they actually are not really able to explain it, I take mental notes and bring to my chamber"*. During a post-session briefing on tugboat operations an instructor responded to a question on why a specific strategy was to prefer by simply stating that *"I felt it was the best idea"*. However, when asked to elaborate on this, the instructor was not fully able to articulate *why* this was a good idea and maintained that it felt right rather than rationally concluding it. The event therefore appeared as semi-conscious or unconscious – a gut feeling. Instructors rarely instructed from the simulator ships bridge (but from the instructor station or during class-room briefings) but when they did it was with the intention of demonstrating a specific maneuver (e.g.). On such occasions, much of the actions were performed seemingly as reflexes. When asked to elaborate further on such actions one instructor explained that *"I do it almost without thinking of it"*. However, to some extent these actions could be articulated and described in crude terms of thrust, angles, headings, accelerations, retardations, and movement when asked to. Thus, qualifying not as tacit but more as implicit knowledge. At other occasions such as meals, coffee-breaks, and off-time in classrooms e.g. informal knowledge sharing also occurred. Telling stories from past events as well as using metaphors were frequent parts on such occasions. A well narrated example or story seemed to evoke a specific *feeling* among the listeners when shared and appeared to function as a knowledge transfer mechanism. Two instructors engaged in a coffee-break conversation shared the opinion that the PPU (Pilot Portable Unit, a device that displays the piloted ship´s movement on a portable screen) was good but that they trusted their gut feeling as well and acted accordingly. However, when asked to expand on the subject one of the instructors commented that the *"PPU is just a picture showing trends of movement, but I can feel the ship relatively to wind and current and so and can therefore anticipate before the PPU what is likely going to happen, especially at that position in that harbor"*. When asked to describe this strategy in more detail, the instructor explained that in different meteorological conditions, certain rules-of-thumb, which in turn were based on sightlines and distances, were used as clues. These rules-of-thumb were based on past experiences and could in fact *"probably be written down in some sort of standard procedure"* according to the other instructor. The gut feeling described therefore appeared to be more of an implicit than explicit or tacit type.

Document analysis. None of the 63 screened documents contained the term *tacit*, *implicit*, or *procedural*, five documents contained the term *skill*, and no document included terms with adjacent meanings. The *Course description* e.g. for the BASIC course states that the student shall have either an understanding, knowledge, or skill in specified areas where skill is a required result from training areas such as controlled navigation, ships handling, and hydrodynamics (e.g.) which are trained in the simulator. However, no documents found contained information on *how* skill is to be achieved in more precise didactical terms. One document, *Instruction for PTP*, contains descriptions of the instructor/supervisor role and responsibilities of creating, maintaining, and improving training modules during the BASIC course. During the BASIC course instructors use these training modules as frameworks and exercised didactical techniques to assure expected learning outcomes. One instructor e.g. stated that *"we have the collective of students discuss a simulator session, sessions that we have filmed and now are displayed live on the whiteboard, to discuss in a group with us as moderators and instructors to share methods of good pilotage"*. Instructors are also active pilots which is beneficial in terms of keeping in touch with the outside world. However, all (13/13) instructors believed that they lacked clear support on didactical and pedagogical questions from an organizational point of view. In a final panel discussion, some instructors (8/13) believed that it was challenging to transform written sections in the course literature into skill. Furthermore, they believed that much of the skill developing situations takes place during the LTP in situ. The *Shiphandler´s Guide* also handily stated *"…words and sentences flow in a sequence, whereas the need in shiphandling is to have an awareness of the whole picture during maneuvers. It is one of the reasons I believe, why it is so difficult to convey the essence of shiphandling in a written text*". The same document also stated that *"…there is much more to ship handling than a book can convey"*.

4 Discussion

This study assessed eye-tracking as a didactical tool in simulator based maritime pilot training as well as its ability to facilitate tacit knowledge transfer during such training. A mixed-method explorative design using questionnaires, interviews, document analysis, and observations collected data from pilots, instructors, and students were used. This study furthermore aimed at increasing the understanding of the prerequisites of using eye-tracking, however not quantifying, and applying inferential statical analysis. The section below is presented as a compilation of Study 1–4.

4.1 Eye-tracking

Objectively, and with good accuracy, assessing eye-movements were appreciated by instructors and students. Establishing a common picture of events is an example of this. However, establishing a common picture does not reveal the complete individual experience of an event. In the present study one instructor questioned how it was possible to know if a student is: "*just looking without actually thinking when he is looking at it* [radar screen] *or maybe he is stressed out and cannot relate to what he is seeing or he is doing some kind of calculation*". The links between fixation and visual attention as well as attention mechanisms, and finally learning outcomes, are not deeply researched yet, but are neither the scope of this study. Ironically, it became apparent that during saccades the participant is more or less blind and that eye-tracking studies therefore were more about eye-fixations than eye-movements. Eye-tracking is furthermore typically used to evaluate individual eye-movements, which was also the case for this study. For the MRM session in Study 4, however, collaborative team tasks were assessed, and two pairs of eye-tracking glasses were intermittently used simultaneously. Maneuvering the ship (e.g.) can be seen as an instrument to highlight human factors such as stress management and communication skills. However, ship handling is also teamwork since pilots, the Master of the piloted ship, tugboat Master, ships officers e.g. must share a general understanding of what has happened, is happening, and is to happen according to the MRM-instructors. Using two pairs of eye-tracking glasses simultaneously on two individuals may be efficient from a resource point of view. However, analyzing interactions between two (or more) individuals required substantially more resources and time. Somewhat strange situations occurred as well when e.g. two individuals wearing eye-tracking glasses looked at each other during a simulator session. Additionally, the lack of a relevant method to assess team interactions in the study resulted in inconclusive data which is in line with what Ziv (2016) also presented when interaction and gaze behavior in a multi-pilot crew was studied.

Heat maps (attention maps) were useful to visualize distribution of sight such as fixation and gaze points, thus showing general viewing behavior compared to only explaining it in words. Understanding where individuals are *not* directing visual attention using an opacity map (inverted heat map) could expand the understanding of individual visual attention. The opacity map was not assessed in this study and should be studied further. Heat maps cannot furthermore provide means for systematic statistical data gathering such as temporal order of fixations or the reason for allocating attention. Timewise, students allocated less attention to navigational instruments, focused closer to the ships bridge when directing visual attention out of the windows and had shorter fixation times compared to experienced pilots. This is partially in line with Forsman et al. (2012), who evaluated novice and expert mariners navigating high speed vessels. Furthermore, they also suggested that expert mariners spent less time on navigational instruments, which was not the case in the present study. This contradiction may be a result of pilot specific skills as such since work is seldom performed on the same vessel, thus the pilot needs to rely on objective data from navigational instruments. Furthermore, pilot students are in fact already experienced mariners transitioning into a new profession. Learning new professional tasks may temporarily alter the students' strategies since they are novices in their new profession.

Gaze plots (scan path maps) showed less visual didactical potential since extended simulator session durations obscured the view due to overlapping gaze circles. Reducing simulator session time or dividing sessions into segments reduced the obscurity but hampered the didactical value due to frequent training interruptions. Nonetheless, data could be analyzed in statistical form post-session but was difficult to convey to others in a didactically useful way. However, gaze plots provided a base for analyzing temporal and directional data thus visualizing scanning patterns. Gaze plots can furthermore visualize scanning *strategies*, and thereby inferring cognitive processes, including prioritizations and the spread (saccades) of visual attention in temporal and directional order. In terms of attention hierarchy, gaze plots can be useful also to optimize user scan patterns as well as the design of interfaces per se on the ships bridge. Developing student visual attention during different parts of a mission can be an example of the first and clustering interfaces together to avoid spread and thereby long eye travel between different areas on the ships bridge can be an example of the latter.

Scanning patterns were valuable as targeted feedback based on eye-movements are valuable to correct scanning *techniques*. Many of the participants used visible triangle shaped scanning patterns dividing attention between i.e., bow-conning-ECDIS in a birthing situation. The components in the triangle shifted to match the given situation. A subsequent issue that requires attention is the notion of these scanning patterns are specific for pilots and not for mariners in general. Refining the issue to identifying optimum pilot scanning patterns (triangles) pilots may be good candidates since they are in general conducting their duties on different vessels. Experts display more effective gaze strategies (such as scanning patterns) compared to novices and achieve higher efficiency by applying attention to the relevant task (Colvin et al. 2005; Kasarskis et al. 2001) as well as making better use of their peripheral vison. Optimal scanning patterns or which scanning patterns that are expert ones remains unclear. Hareide and Ostnes (2017) has suggested a front-to-side scanning pattern to establish systematic scanning patterns on board.

Live-streams were assessed in three ways: as recorded data, as recorded live-stream videos, and as real time live-stream videos. Recorded videos can be an effective way, in didactical terms, to convey feedback where instructors and students may evaluate gaze behavior, used as basis for post-session briefings in groups and/or in solitude, and used as well by instructors and students to create a common understanding of events and actions. The latter is important in terms of accountability since objectivity may be degraded or lost due to instructor subjectivity. However, subjectivity is important nonetheless since different instructors visualize different ways of approaching events in the very dynamic maritime environment. Live streams may resolve this challenge by providing accountability as well as diverse solutions to different events.

Heat maps and briefings combines didactical advantages of using heat maps and briefings pre-, mid-, and post-session. Performing briefings in groups – which were a common strategy during the study – is based on shared talk throughs where an animation of a specific simulator scenario is displayed. Displaying different eye-movement strategies and discussing these strategies during post-session briefings can be an anchor point for the development of specific pilot skills in terms of tacit knowledge. Such briefings are however dependent on mutual trust within the group where instructors have an imperative function as enablers of such an environment.

Technical topics. Live-stream link quality, software compatibility with other technical equipment, calibration of glasses, complexity of measurements, or post-session data analysis and presentation are examples of issues that required attention to assure a result as accurate as possible. A wearable eye-tracking system (embedded in a pair of glasses) was used since a fixed eye-tracking system (embedded in a display) was difficult to install technically and run operationally in the ships bridge simulator. A fixed eye-tracking system furthermore require the participant to maintain a fixed head posture making movements difficult on the ships bridge. However, such an eye-tracking system offers simplicity when mapping and calibrating the environment to eye-movements. Mapping the environment for the wearable eye-tracking system resulted in a reduced data output during post-session data analyzes but more flexibility in terms of participants freedom of movement on the ships bridge.

Human factors topics. The infrared mobile eye-tracking glasses used in this study was not suitable for all participants. The mobile eye-tracking glasses could not consistently manage bifocal or varifocal glass lenses since the lenses distorted the shape of the pupil which in turn caused detection and calibration errors in the eye-tracking software. Miscellaneous coatings (anti-glow e.g.) also disturbed tracking of the corneal reflection. In terms of single prescription glasses or reading glasses a magnetic clip (with set corrections) may resolve some issues, but this was not utilized in the study. Single prescription contact lenses resolved the issue with using glasses underneath eye-tracking glasses but had the same issues in terms of varifocal and bifocal corrections as for glasses. Most of the students were just below, at or above middle age and thus in many cases required corrective lenses. This must be considered when planning eye-tracking studies in terms of the participant sample and when calibrating eye-tracking equipment. As well as enrolling soft- and hardware experts, an optician may be required to assure adequate research and mitigate issues with glasses and corrective lenses. Difficulties maintaining the required head posture and not gazing down below the eye-tracking glasses were a common issue during the studies. Having participants accustomed to the glasses during trial sessions may be a way to mitigate such issues. Some participants also reported that being observed, and being assessed, via your (own) eyes was stressful. To add more stress using eye-tracking in an already stressful situation, such as a test or evaluation session, can have a negative impact on the performance. However, in this study all participants had already either been accepted as students or were already pilots which might have lessened the extra stress. Nonetheless, eye-tracking may be useful when conducting evaluations such as usability tests of navigational equipment or nautical procedures and evaluations of individual performance. Human factors based issues may result in ambiguous results when using eye-tracking and need to be thoroughly understood.

Methodological topics. Conducting research based on eye-tracking is resource consuming in terms of staff, equipment, competences, methods, and e.g. time. Thus, requiring an array of experts in different fields to assure validity and reliability. All instructors were experienced mariners as well as experienced pilots which makes them subject matter experts, however not eye-tracking experts. Distinguishing voluntary eye-movements from involuntary eye-movements is an example of such an issue. Duration wise saccades (30–80 ms) and micro saccades (10–30 ms) are similar events but represent voluntary versus unvoluntary eye-movements, smooth pursuits (slowly following an object) and drifts (200–1000 ms) are similar events as well but also represent voluntary versus unvoluntary eye-movements, or tremors (ocular muscle oscillation) which is also an involuntary eye-movement. Unintentional or unvoluntary eye-movements consequently disturb the research process and require specific expertise to be mitigated. It is therefore difficult to draw conclusions from this study, other than general, based on eye-tracking solely even if triangulation has been used in the study as well. Measurement of biometrics such as heart rate and stress levels are suggested as complementary means to enhance eye-tracking metrics.

4.2 Tacit knowledge and tacit knowledge transfer

The pilot contributes with extensive local knowledge since the local navigational chart is not complete and cannot cover all local peculiarities. In a way the pilot acts as a human sensor with an internal set of extensive navigational data bases accessed via the long-term memory. Pilot specific tacit knowledge appear to consist of extensive local waterway knowledge in terms of navigation, infrastructure, procedures, and local meteorological conditions e.g. However, specific pilots' skills also include the ability to interact with the crew of the piloted vessel in terms of communication, providing navigational advice, how to establish leadership and balance authority, flexibility, and set targets e.g. The overall results show that tacit knowledge and tacit knowledge transfer in terms of *pilot* specific skills were not conclusively detectable during the simulator part of the training but ships handling skills were and that some of the pilot specific skills were trained at the MRM-part of the PTP.

Methodological topics. Studying tacit knowledge is challenging since it is a form of knowledge that is gained through individual experiences (technical, emotional, perceptional) and differs from one individual to another and is very difficult or impossible to articulate. Sharing experiences (socialization) where tacit knowledge is converted to tacit knowledge seem to occur between individuals simply spending time together. This seems to be valid also for converting explicit knowledge to tacit knowledge (externalization) but is more depending on dialogues between peers where metaphors and mental models e.g. can be instruments for converting tacit knowledge to tangible concepts. Using eye-tracking as a didactical tool to distinguish between socialization and externalization is challenging and even triangulation may be insufficient to mitigate such challenges. Triangulation was, however, a key element primarily used to increase the validity and the reliability of emerging data and findings. Validity refers to the extent of which a measure manages to measure its intended construct (Landy, 1986; Nunnally, 1967). Internal validity issues were prominent since operationalizing tacit knowledge relies on subjects articulating things that cannot, or is very difficult, *to* articulate. Even if deploying complementing methodologies such as interviews, questionnaires, and document analyzes aiming at internal validity such efforts may not be sufficient. In terms of reliability, when assessing the present research procedure, obtaining the same results consistently is not feasible. Instead, agreeing that based on data collected, a consistent and visible method is applied in terms of results and findings. Again, the same problem as with validity apply how can the qualitative data be triangulated if such data is difficult or even impossible to articulate. However, for a qualitative or a mixed-method design approach other measurements may apply. Whittemore, Chase, and Mandle (2001) described four primary key validation criteria: credibility (accurate interpretation of the meaning of the data), authenticity (accurate reflections of participant experiences), criticality (research critically appraised), and integrity (self-critical researchers). Credibility assessments were continuously applied to align the meaning of data from an interview e.g., via an accurate interpretation, to the result and further analysis. Authenticity assessments were used to assure that the participants could interact with the research team in a natural and unobstructed fashion. Criticality was assured by actively looking for alternative explanations or follow up non-congruent data and integrity was assured by continuously striving for self-criticism to avoid biases.

Tacit knowledge, learning, and reproduction of skills. Defining what tacit knowledge is and how it can be studied is challenging. Several definitions, e.g. scholarly, operational, didactical, pedagogical, and cultural, sometimes overlapping, appeared during the study which is also in line with e.g. Collins (2010) view that tacit knowledge resides in different faculties. In terms of topics instinct, reflex, intuition, gut feeling, and muscle memory were common and sometimes interchangeably used during conceptualizing. There is, however, a disconnection between these topics and their scholarly meaning. Instincts, which can be viewed as innate inclination towards a particular behavior and reflexes which are innate and involuntary responses to stimulus (Fisher and Truog 2015) have no learning elements and are thus difficult to fit into the studies of tacit knowledge and its transfer. However, mimicking an instinct driven behavior could reflect socialization. Intuition (gut feeling) is described as unconscious reasoning and pattern recognition by Garrety (1986), as an emotional (affective) processes in which judgements also have importance (Saddler-Smith 2008) and is often regarded as an automated and unconscious base for decision making. The "*more*" in Polanyi´s (1967) assertion that "*we can know more than we can tell*" may very well be intuition and is according to Kahneman (2011) also equivalent to recognition. From that perspective pilot specific skill combines explicit and implicit knowledge on specific waterways and as a base for decision making, also pattern recognition established over time in *different* vessels but on the *same* waterway. In terms of learning, intuition formulated as pattern recognition seem to facilitate learning when students reflect on things they have trained. One student expressed this as "*I´m connecting the dots when I remember similar events or even when I hear other talk about* [their] *experiences from the trade"* which can interpretated as internalization. Intuition might be an important when identifying what pilot specific tacit knowledge is: a cognitive dimension manifested as intuition (pattern recognition from previous pilotage events) and a technical dimension manifested as know-how in a specific context (local piloted waterways) interacting with each other. This is in line with Gigerenzer (2007) who describe gut feeling as rules-of-thumb (heuristics) interacting with evolved capacities of the brain (recognition). Muscle memory (also referred as motor memory, procedural memory e.g.) developed during continuous repetition involving both cognitive as well as motor skills and resulting in actions without conscious effort, can be regarded as implicit memory as well (Shusterman 2011). Muscle memory may be more affiliated with ships handling than pilot specific skills. During the simulator parts of the PTP explicit and implicit knowledge was present and transferred in terms of literature e.g. in the first case and best practices e.g. in the second case. Best practices were procedures, strategies, or rules-of-thumb e.g. articulated by instructors by speech but not in written form. It could be formulated in text but was not yet. Generating a best practice video, based on eye-tracking to be used as a part of the course booklet, can be a way to facilitate pilot specific knowledge transfer. Such a video was assessed in Study 4 and included video and audio information on fixations, scanning patterns, navigational instruments, and real-time comments from the pilot. Pilot specific skills seem to develop more during the LTP where students perform pilotage supported by an experienced supervisor during 50–150 actual missions gaining experience in social settings. A local library at the LTP station including such videos could be contributing means to transfer knowledge, and possibly standard operating procedures, to the student as well to future students. Throughout briefings instructors reviewed simulator sessions, using recorded live-stream videos based on eye-tracking supported by animations from simulator movements, in class-room environments together with the students. Instructors often directed these briefings to facilitate understanding, problem solving, and creation of best practices by using guided discoveries (Overholser 2012). Thus, the combined experience among the students was also used as a didactical tool: by using videos as a base, stories, examples, analogies, or metaphors etc. as vessels, a feeling from the event can be created which in turn can serve as a key to transfer tacit knowledge (Backlund and Sjunnesson 2006). In addition, rules-of-thumb emerging from briefings can also serve as anchor points for tacit knowledge transfer as "*approximated summaries of previous experience"* (Backlund and Sjunnesson 2006). During the study it became apparent that pilotage – as trained – was much about controlled navigation, ships handling, and hydrodynamics. However, such skills are not unique to pilots but apply to all Masters. These skills are however trained systematically to higher standard using volume training using different vessels, harbors, and meteorological conditions e.g. Efforts was also made training students as a temporary and *indirect* crew member of the piloted vessel. Thus, non-technical skills such as communication, decision making, and social interaction were incorporated in the volume training. Developing nautical assertiveness, based on volume training in simulators, in combination with the development of knowledge on local waterways seem to be in line with specific pilot skills. However, it remains unclear if the reproduction of specific pilot skills is a question of tacit knowledge or alternatively know-how (volume training) combined with pattern recognition (experiences from different vessels on the same waterway). It also seems likely that feasible tacit knowledge transfer events contain more of articulated rules, procedures, or operational descriptions than tacit knowledge (which cannot be articulated).

The simulator. Maritime simulators are a well-established didactical tool to train, evaluate and certify maritime professionals. Basic rationales for using a maritime simulator are the possibility to e.g. reduce the amount of time spent on actual vessels, to reduce the cost of training on actual vessels, and to train scenarios that are difficult or unsafe to train on actual vessels (Barsan 2009). Simulator sessions can furthermore be regarded as a mean to substitute experience building activities from apprenticeship type environments such as actual vessels with a simulated environment. Specific pilot skills however seem to be developed during other parts of the PTP and are not performed in simulated environments. The MRM-part in Study 4 is an example of this since MRM aims at training and developing non-technical skills such as communication, interaction, and decision making e.g. which are prerequisites of pilot skill. To utilize simulators efficiently, several requirements also need to be assured. Running a maritime simulator without e.g. a pedagogical and didactical framework does not assure that set training targets are achieved (Hontvedt and Arnseth 2013). Furthermore, simulator operations are more instrumental compared to actual environments which require a mix of technical skills (ships handling, navigation, systems knowledge e.g.) as well as non-technical pilot skills (communication, social interaction, Master-Pilot exchange, decision making e.g.). Simulator operations may therefore not mirror actual pilotage from important perspectives which need to be reflected in pedagogical and didactical documentation.

5 Conclusions

The objective of this study was to evaluate eye-tracking in simulator based maritime pilot training as a didactic tool as well as facilitator of tacit knowledge transfer.

5.1 Eye-tracking

- Eye-tracking is usable as a support during PTP simulator training in terms of visualizing attention, scanning, gaze behavior, and as a mean to support simulator session briefings.
- A systematic implementation of eye-tracking in terms of establishing pedagogical and didactical documentation is required to reach set training objectives.
- Effective utilization of eye-tracking requires considerable resources in terms of time, equipment, infrastructure, staff, and training of staff by the PTP organization.
- Physiological prerequisites among participants such as corrected vison and head posture requires mitigation.
- Using eye-tracking to assess collaborative task performance lacks a specific methodology.
- Links between visual attention, cognition, and learning are not clear and require more research.

5.2 Tacit knowledge transfer

- The reproduction of pilots' tacit knowledge was not observed during the simulator part of the PTP except during MRM-training.
- It is unclear if the reproduction of specific pilot skills is based on tacit knowledge transfer or on development of know-how (using volume training) combined with pattern recognition over time (experiences from different vessels on the same waterway).
- Pilot specific skills such as controlled navigation, ships handling, and hydrodynamics was initially regarded as plausible tacit knowledge nodes but were subsequently assessed as generic for any Master.
- Using volume training, pilot specific skills were systematically trained to a higher standard.
- Developing pilot specific skills are in terms of guided experiences during apprenticeship predominantly located at the LTP-part of the PTP.
- Identified tacit knowledge transfer events may contain more of articulated rules, procedures, or operational descriptions than tacit knowledge.

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9. CONFERENCE KEY-NOTE PRESENTATION

Full-mission simulation training risk factors – and how to avoid them

Charlott Sellberg

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University of Gothenburg, Sweden

Sellberg, C. (2022). *Full-mission simulation training risk factors (and how to avoid them).* Nautical Institute 50-year Anniversary. Organizer: the South African Branch of the Nautical Institute, October 2022.

GÖTEBORGS UNIVERSITET

FULL-MISSION SIMULATION TRAINING RISK FACTORS (AND HOW TO AVOID THEM)

CHARLOTT SELLBERG, DEPARTMENT OF APPLIED IT, UNIVERSITY OF GOTHENBURG

THEORETICAL PREMISES

Situating cognition and learning in the social and material world of culturally constituted interactions

Learning in and through socio-material practices

- Studying trajectories of learning in observable interactions
  - Analysis of *how* things are taught, i.e., becomes learnable (*didactics*)
  - Analysis of *what* is being taught and possibly learnt (*object of knowledge*)
  - Analysis of *why* participants might learn from a particular teaching practice (*pedagogy*)

➢ Studying cognitive activities without trying to study mental representations

Lynch, M. (2006). Cognitive activities without cognition? Ethnomethodological investigations of selected ‘cognitive’topics. *Discourse Studies*, *8*(1), 95-104.

Methodological implications

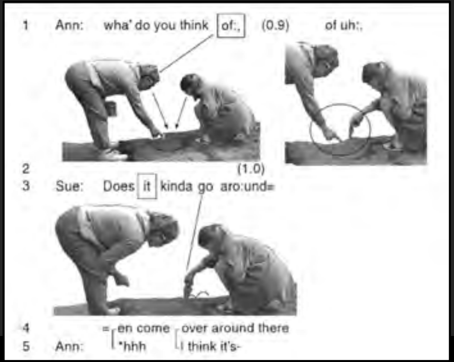
- Studying *naturally occurring* learning practices *in situ*
  - Ethnographic fieldwork
  - Informal interviews with *participants as experts*
  - Aiming at gaining "*vulgar competence*"
- The sequential order of *talk* and *bodily conduct* in the *material world* as the unit-of-analysis
  - Collecting video data in the field
  - Aiming at creating stable records for detailed analyses

Luff, P., Hindmarsh, J., & Heath, C. (Eds.). (2000). *Workplace studies: Recovering work practice and informing system design*. Cambridge university press.

The unit-of-analysis

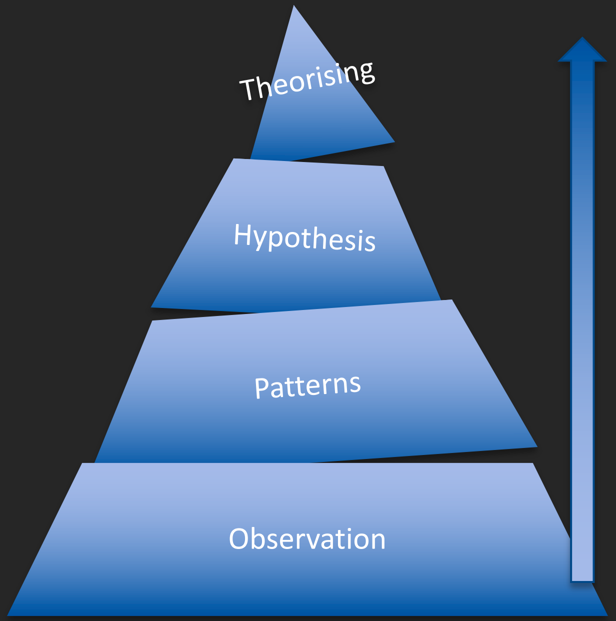
- Talk and bodily conduct in the material world as the unit of analysis
  - The sequential order of interaction
  - Multimodal transcripts
  - Pictures from the data to display the participants bodily conduct

Goodwin, C. (1994). Professional vision. *American anthropologist*, 96(3), 606-633.



Research approach

- *Empirically driven* approach
- Results are based on the *premises for action* in the specific context observed
- Moving from *specific observations* to *broader generalizations* about a phenomenon → theory building



AUTHENTICITY, ROLE-PLAY AND SIMULATION

In-scenario corrections in maritime training

Authentic representations of work

- Role-plays to mimic “real-life” professional encounters
  - Creating a work relevant *activity context*
  - Train students for the hierarchies, work roles and work practices of a profession
  - Might come in conflict with instructional needs
    - Asking for help
    - Corrections
    - Assessment

Hontvedt, M., & Arnseth, H. C. (2013). On the bridge to learn: Analysing the social organization of nautical instruction in a ship simulator. *International Journal of Computer-Supported Collaborative Learning*, 8(1), 89-112.

Research aim

- The aim is to explore instructional dilemmas between sustaining authenticity through role-play and need for in-scenario corrections
- An episode of video-recorded data chosen as an example from a larger data corpus of simulation-based training

Empirical case

- Navigation course
  - Radar/ARPA technologies
  - Following COLREG
  - Bridge team work
- Participants
  - 40 students
  - 3 simulator instructors
- Video-recorded data
  - 5 simulator exercises
  - 30 hours of training
  - 7 cameras filming

Correcting rule-following in role-playing mode

Stu: Deep surveyor… Cilla is here

Ins: Yes. I have a cable stern away so please keep at least a mile astern or go at least zero point five ahead of me. Over.

Stu: A mile astern… Oh! Or one zero five ahead… Okay.

Ins: Yeah. Thank you. Back to sixteen!

Stu: Okay

Clarifying the correction

After a few minutes…

- Call back to the students' bridge (in Swedish)
  - Instructor asking if they have checked their AIS
  - Student replies that they haven't
  - Instructor tells students to do so
- Reveals the lesson to be learned

Sellberg, C. (2018). From briefing, through scenario, to debriefing: the maritime instructor's work during simulator-based training. *Cognition, Technology & Work*, 20(1), 49-62.

Findings

- Instructors’ corrections during role-play might not be heard *as* corrections by students
- Instructors’ practice of leaving the role-play in order to clarify corrections shifts the focus of the activity: from the professional realm to the educational context
- Our conclusion is that these movements are important for simulation training to fulfil its pedagogical potential

THE DEVELOPMENT OF VISUAL EXPERTISE IN A VIRTUAL ENVIRONMENT

A case of maritime pilots in training

Problem area

- No matter how technically advanced the simulator is, there will always be “glitches”, i.e., imperfections and inconsistencies between the simulator environment and the work context (Rystedt & Sjöblom, 2012)
- Glitches can be seen as a problem, leading to so called “negative skills transfer”, i.e. students learning to manipulate the simulator rather than shiphandling (Hontvedt, 2015)
- Glitches can be seen as an instructional resource, i.e., opportunities to discuss the simulation in relation to work practices and work contexts (Hindmarsh et al. 2014; Sellberg, 2017)

Aim and research questions

- The aim is to carefully examine the risk of negative skills transfer when training in a simulator environment, directing the analytical focus towards maritime pilot trainees' talk about imperfections and inconsistencies in the virtual environment during exercises in a high-fidelity bridge simulator to answer the following research questions:
  - How do trainees handle imperfections and inconsistencies in the virtual environment during visually demanding tasks?
  - What are the implications of handling imperfections and inconsistencies for the development of visual expertise in maritime pilot training?

Empirical data

- Filming in a course on advanced shiphandling
  - 2 instructors and 6 trainees
  - 4 days of training on 3 bridge simulators
  - Briefing-scenario-debriefing
  - Approximately 130 hours of video recorded training
  - 30 instances of talking about “glitches”

Preliminary results

- Shiphandling in a simulator is a rather different activity than shiphandling a seagoing vessel (cf. Hutchins, 1995)
  - At the *computational level*, the algorithms for of determining distance, speed and turn ratio are the same between conditions
  - Different strategies for gathering visual information (*representational level*)
  - Different strategies for understanding movement, i.e., the details of how the algorithm and representation are realized physically (*implementational level*)

Preliminary results

- Rather than to warn for “negative skills transfer” we want to highlight how the pilots in training are able to articulate and conceptualize the simulation towards the practice on board seagoing ships, showing awareness of the different levels or layers of professional expertise
- Simulation training and training on board are practices that are *mutually advancing* the pilot’s expertise in shiphandling in their trajectory towards mastery skills
- We also want to highlight the importance of learning to perform advanced simulations in safety critical professions, training to be prepared for a number of possible events

Discussion

- The instructors’ role of monitoring students and intervene when they are in need of instructional support
  - When the simulator lacks in fidelity
  - When they seem to not hear an instruction *as* an instruction
  - To follow up discussions on simulator practice vs professional practice in debriefing
- The multidimensional notion of simulator fidelity
  - Technical fidelity
  - Environmental fidelity
  - Psychological and social fidelity

Read more…

Hindmarsh, J., Hyland, L., & Banerjee, A. (2014). Work to make simulation work:‘Realism’, instructional correction and the body in training. *Discourse Studies*, 16(2), 247-269.

Hontvedt, M., & Øvergård, K. I. (2020). Simulations at work—A framework for configuring simulation fidelity with training objectives. *Computer Supported Cooperative Work (CSCW),* 29(1), 85-113.

Rystedt, H., & Sjöblom, B. (2012). Realism, authenticity, and learning in healthcare simulations: rules of relevance and irrelevance as interactive achievements. *Instructional science*, 40(5), 785-798.

Sellberg, C. (2017). Representing and enacting movement: The body as an instructional resource in a simulator-based environment. *Education and Information Technologies*, *22*(5), 2311-2332.

Thank you for listening!

10. CONFERENCE PRESENTATION

Transferring Tacit Knowledge in Safety-Critical Systems

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Osvalder, A-L. & Eklund, R. (2022). *Transferring tacit knowledge among operators in safety-critical systems***.** Abstract at the Nordic Ergonomics & Human Factors Society Conference 2022, October 23-25, Uppsala, Sweden.

Transferring tacit knowledge among operators in safety-critical systems

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Safety-critical systems, such as process industry, aerospace, shipping, transportation, and medical care, are dependent on the knowledge embedded within their operators. Experienced operators, who have worked in a safety-critical organization for a long time, possess extensive knowledge on operation and control of the technical systems. Over time, operators might leave the organization, including the knowledge and experience they have gained during their careers, subsequently leaving a partly depleted organization behind. Embedded knowledge can be referred to as tacit knowledge, implicit knowledge, know-how, or simply skill, all which are competences difficult to verbalize or transform into written text. Therefore, it is vital for a safety-critical organization to establish methods to identify, document, and transfer tacit knowledge among the operators. By taking such actions, an organization can be more resilient in terms of knowledge management.

The purpose of this paper is to discuss how tacit knowledge is transferred among operators in safety-critical systems. Two empirical studies, complemented with a systematic literature review, have been used for this purpose. The literature review focused on establishing an overview of the research domain. The empirical studies focused on maritime pilot training and process room control operation, respectively. A mixed-method approach to achieve triangulation, including document analysis, observations, interviews, and questionnaires was deployed. The methods established how and when tacit knowledge was used in the two domains, how it had been acquired, and how it was transferred.

The results showed that a significant amount of tacit knowledge was transferred in social settings, such as on-the-job activities, apprentice- or internship, and in social contexts during coffee breaks as well as in other informal and spontaneous settings. Tacit knowledge was consequently transferred to others primarily through socialization, but not clearly documented, which made it difficult to understand the processes of tacit knowledge transfer. During the maritime pilot training learning activities included interaction with experienced maritime pilot instructors during pilotage and with the bridge crew, as well as with tug or mooring boats. In process control room environments, experienced individual

operators as well as complete teams, stood for vital tacit knowledge about operation and control of the plant. This knowledge was not clearly documented, and few formal methods were used for tacit knowledge transfer. The literature review showed limited interest to the area of tacit knowledge transfer in safety-critical systems. However, a few organizations have implemented an array of methods assuring tacit knowledge transfer. The results showed that situated learning in communities of practice, such as apprenticeship and interacting with others in a social process, facilitates tacit knowledge transfer, while technical methods showed to have a limited effect.

To conclude, operators in safety-critical systems show extensive embedded knowledge in terms of how to establish continuous, effective, and safe operations. However, their individual solutions are not easily available for others and are in essence informal. Some organizations are using formal, standardized, or technical methods for transferring tacit knowledge among their operators. Tacit knowledge transfer is, however, mainly achieved in terms of socialization, a method that is effective yet difficult to document and subsequently to study and improve.

Keywords.
Tacit knowledge · Maritime pilotage · Operator control · Process industry · Expertise · Socialization

Transferring Tacit Knowledge in Safety-Critical Systems

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CHALMERS



Agenda

- Background
  - Knowledge transfer in organizations
  - Definition tacit and explicit knowledge
  - Knowledge conversion (Nonaka's model)
- Empirical studies: Process operation control, maritime pilot training, flight operations
  - Purpose and methods
  - Characterization of process control
  - Results
  - Conclusion

Tacit knowledge in organizations

- Few organizations have adopted knowledge transfer as part of their working process or using formalized methods for transferring tacit knowledge
- Evaluations seldom made if knowledge transfer has been accomplished or which effects it might have given
- In safety critical organizations, only the nuclear sector *systematically* preserve competence within the organization, especially for unexpected events

Knowledge

Knowledge is a mixture of:

- Experience
- Compiled information
- Insight

Knowledge can be divided into:

- Explicit (verbalized) – know what
- Implicit (non-verbalized) – know how

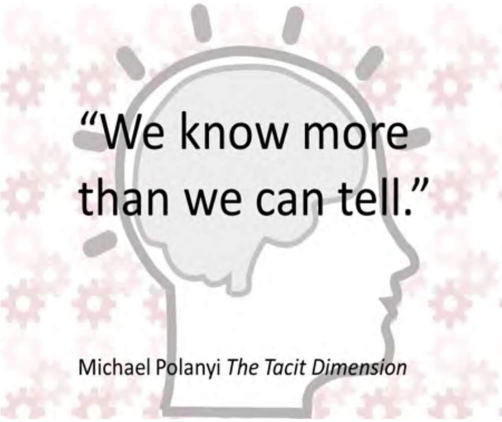
Explicit & Implicit knowledge

Explicit:

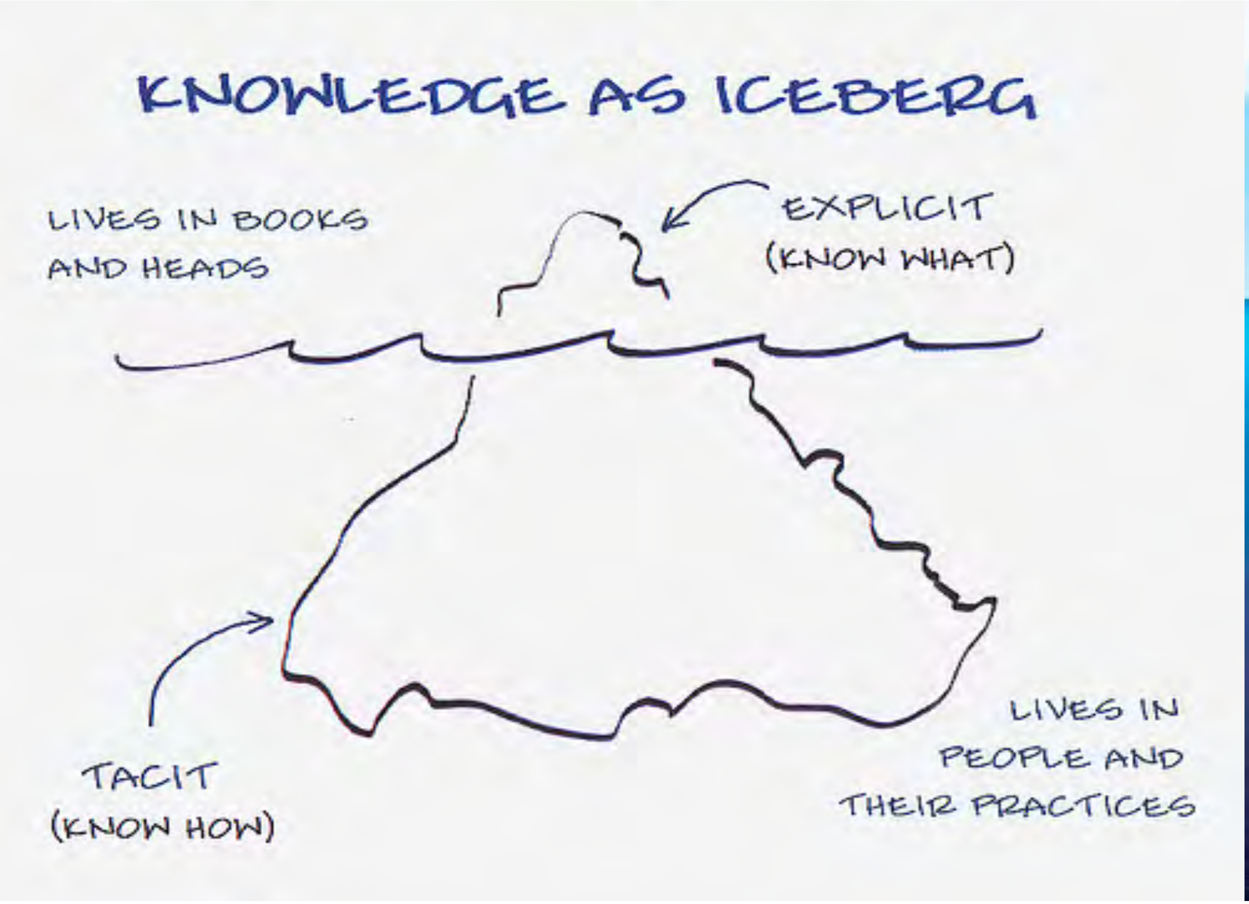
- Can be verbalized in text
- Develops through active search & education
- Conscious about what you can!

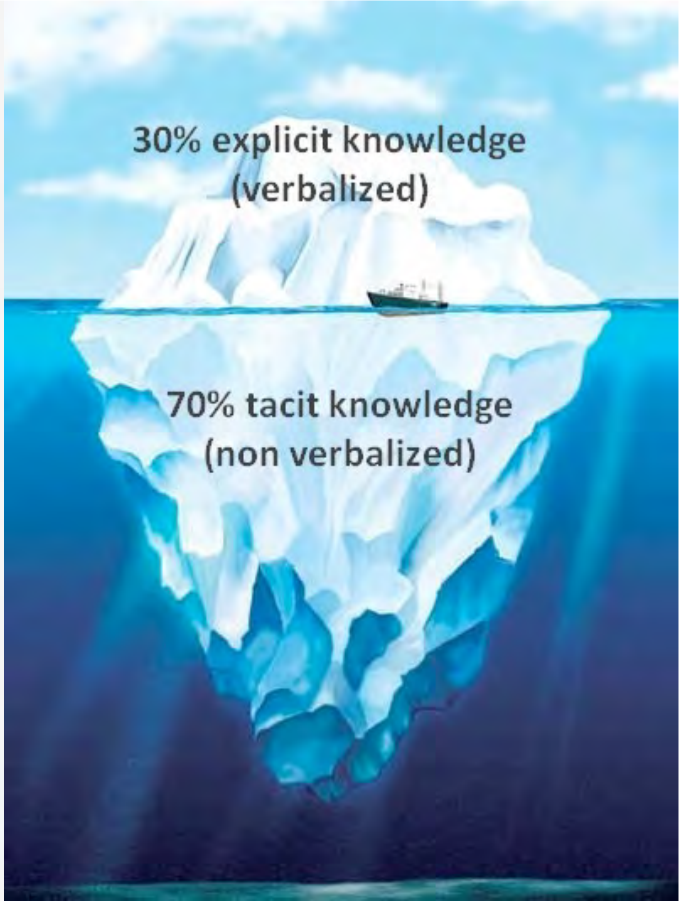
Implicit (tacit)**:**

- Not easily accessible for verbalization without explicitly showing how to do
- Develops through practice over a long period of time
- Unconscious about what you can!

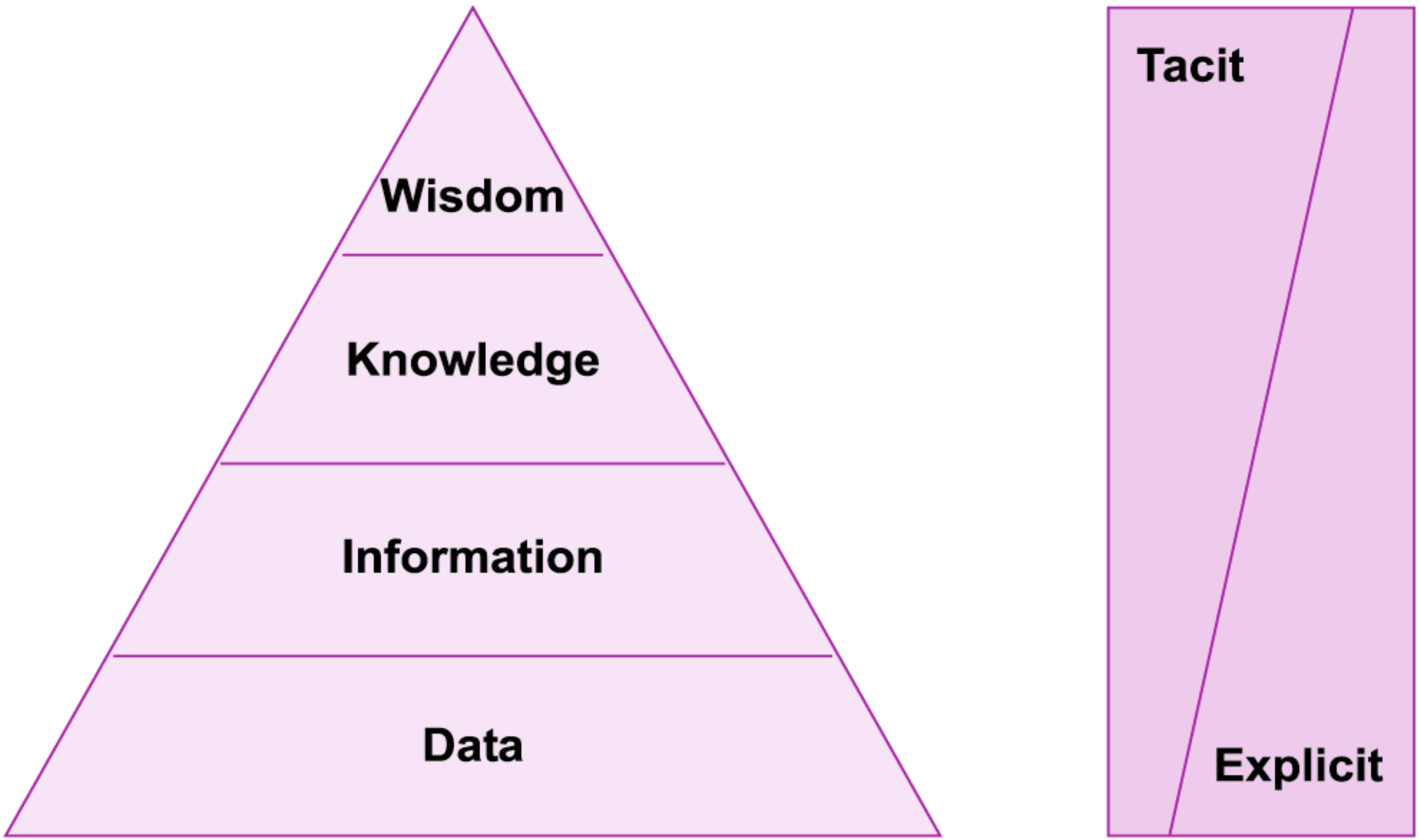


Knowledge as an iceberg





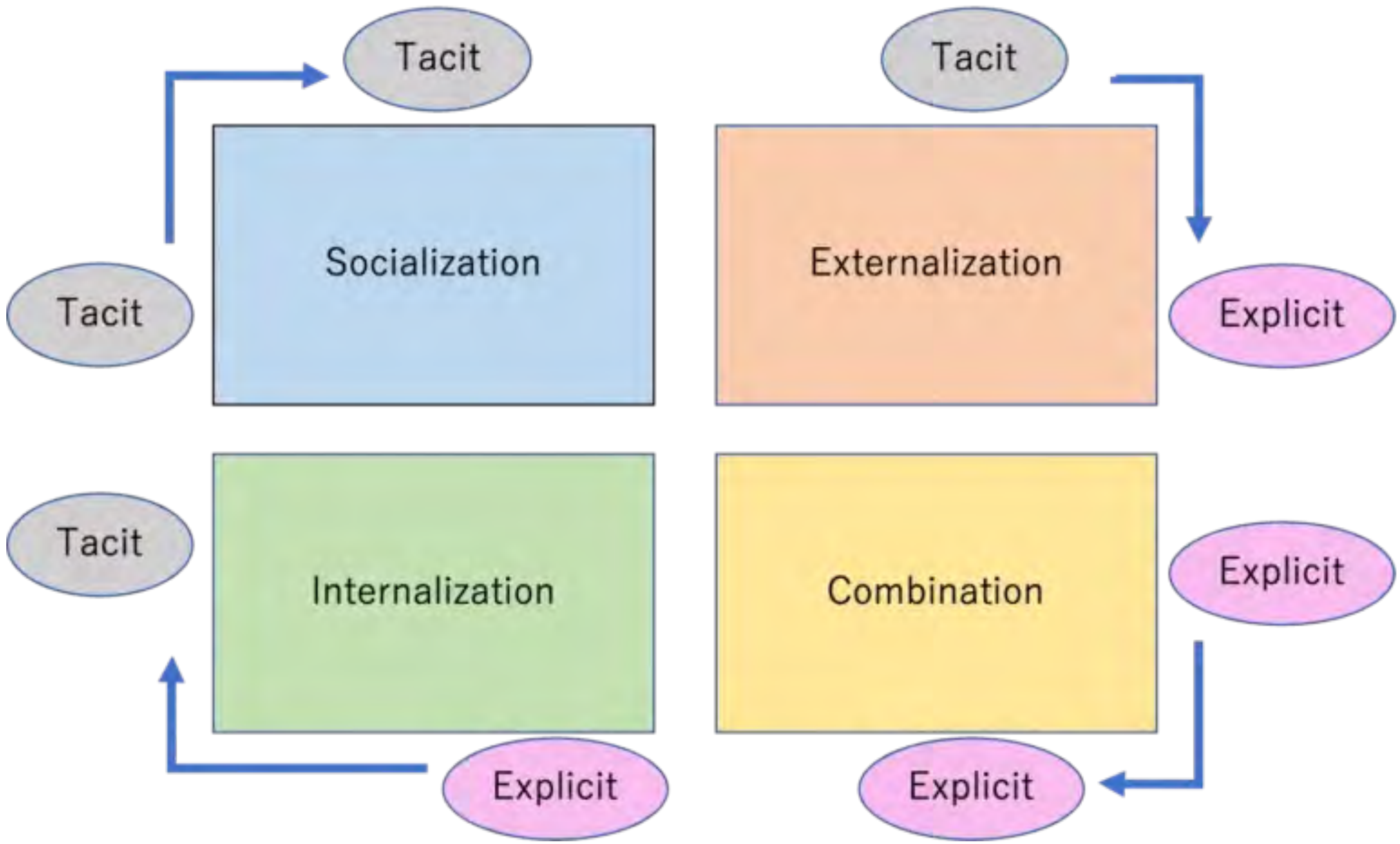
Knowledge conversion



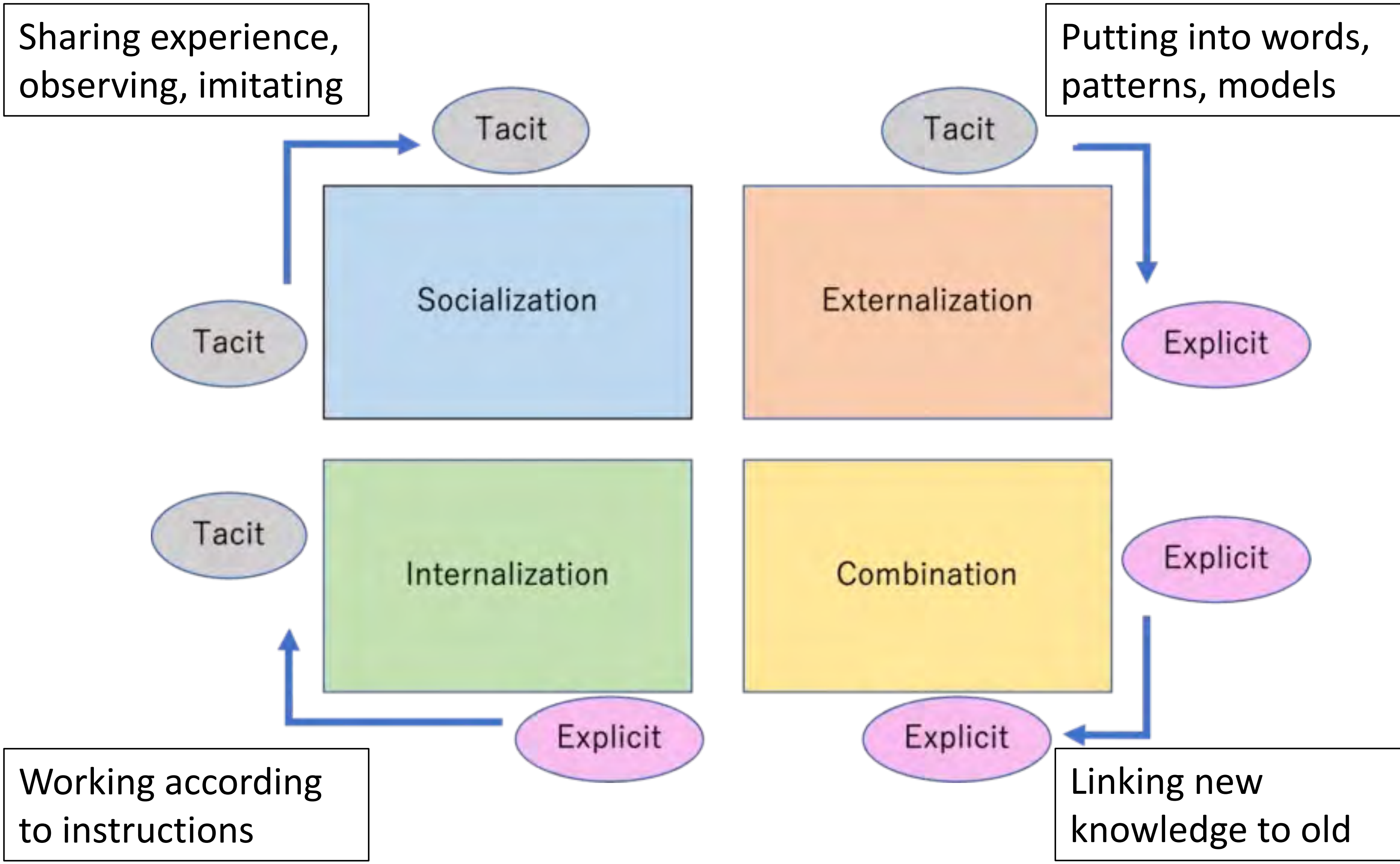
Understanding: The basis of the conversion process

Knowledge conversion

Nonaka & Takeuchi (1995)



Knowledge conversion



Purpose of the empirical studies

- To compare suitable methods for finding and transferring expert operators’ tacit knowledge
- Propose methods or techniques to enable tacit knowledge transfer
- Collaboration with the process, aerospace and maritime domain

Methods

- Literature studies
- Organization

  - Focus groups, work-shops, interviews, document analysis
- Control room, ships bridge and flightdeck

  - Observations, interviews, questionnaires



Characteristics of the domains

- Complex automated socio-technical-systems
- Operation 24h/7 days, some in shift-teams
- Abstract, non-transparent processes
- Dynamic process with unexpected events
- Dynamic operations with shifting environment
- Much and various information support
- Sometimes delayed feedback & cognitive bottlenecks (attention, short term memory, long term memory retrieval…)



Characteristics of the domains

- **Operator demands**:
  - correct mental model
  - high situation awareness
  - follow-up procedures
- **Socialization:** Several years to develop expertise through
  - internship and team-work (learning by doing)
  - simulator and class-room training



Results tacit knowledge

- Operators’ working experience 15-40 years
- The operators have extensive tacit knowledge
- Operators rely much on own experience, shift-team competence and standard operating procedures (SOPs)
- The tacit knowledge is
  - not available for other operators or shift-teams
  - not documented, communicated or reachable in the organizations

Methodology: knowledge transfer

1. Methods for mapping the working situation
2. Methods to find the tacit knowledge
3. Methods to transfer the tacit knowledge
4. Methods for creating explicit knowledge and documentation

1. Mapping the working situation

- Working tasks (task analysis), system theory, activity theory, document analysis
- Gap analysis: work as imagined versus work as done
- Identifying experts and novices
- Information sources & decision-making supports
- Disturbances and incident scenarios



2. Methods catching tacit knowledge

- Which cues, patterns and system feedback are used to understand and solve problems, and predict the future?
- Which heuristics and rules of thumb are used for operation?
- Observations in the control room
- Think-aloud method during work
- Scenario-analysis of disturbances (workshop with expert operators)
- Interviews
- Diaries, journals, or records

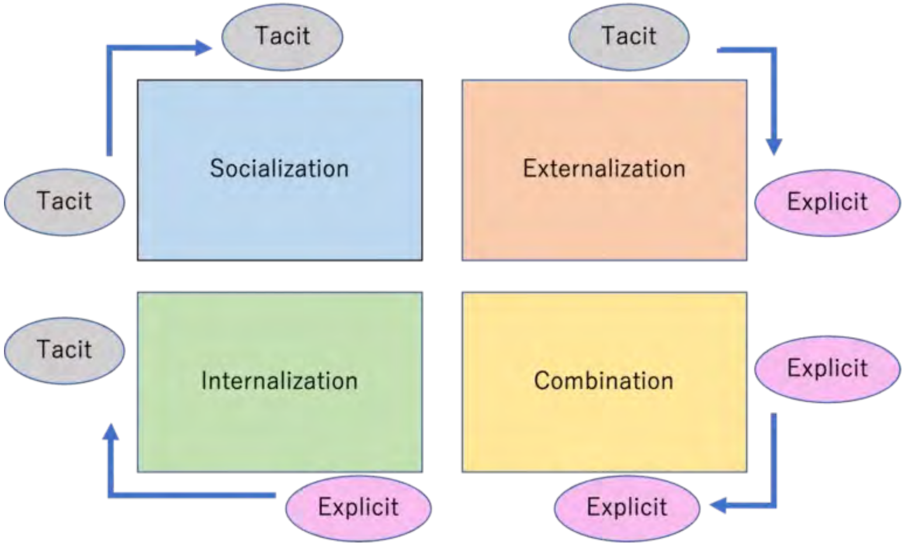
3. Methods transferring tacit knowledge

- Scenario analysis of disturbances in focus groups
- Role-play between tutor and adept (experienced and novice operator)
- Pre-briefing, mid-briefing, and post-briefing during training sessions or on-the-job training

- Informal and spontaneous methods
  - Internship
  - Work rotation in the shift-teams
  - Social activities
  - Coffee machine talks
  - Embedded learning during off time

4. Methods for documentation
(creating explicit knowledge)

- **Externalization:** checklists, written documents
- **Combination:** strategies for problem solving, rules of thumb
- **Internalization:** incident report system, lessons learned



Conclusion:
Successful knowledge transfer

- Interest, resources and follow-up in the organization
- Access to a typical work environment for learning & training (simulator or real life)
- Access to saved non-normal operations/scenarios (incidents and accidents)
- Motivated experienced operators with verbal skills and interest in knowledge sharing
- Document and communicate activities
- Using standard operating procedures (SOPs)

Transferring Tacit Knowledge in Safety-Critical Systems

Anna-Lisa Osvalder & Rikard Eklund

Design & Human Factors
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Gothenburg, Sweden

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RESEARCH REPORT 11

AHFE CONFERENCE SESSION

San Francisco, USA, 20-23 July, 2023

Human Factors in Transportation: Maritime track

Panel: Eye-Tracking as Instructor Support in Professional Education and Training: Findings from a Cooperation Between Research and Practice
Co-Chairs: Gesa Praetorius and Charlott Sellberg, Sweden
1. Enhancing professional education through technology – a joint research approach to the usage of eye-tracking in maritime pilot training Anna-Lisa Osvalder, Chalmers University of Technology, Sweden
2. The ambiguous nature of visual expertise - Insights from using eye-tracking data for video-stimulated reflection in maritime piloting Andreas Edvall, Swedish Maritime Administration Charlott Sellberg and Elin Nordenstrom, Gothenburg University (GU), Sweden
3. Applied cognitive task analysis (ACTA) of marine piloting in a Swedish context Cecilia Berlin, Chalmers University of Technolgy & Gesa Praetorius, VTI, Sweden
4. Transferring Tacit Knowledge in Safety-Critical Systems: Examples from maritime pilot training Rikard Eklund & Anna-Lisa Osvalder, Chalmers University of Technology, Sweden
5. Expertise and implication for technology-enhanced assessment in professional training Charlott Sellberg (GU), Gesa Praetorius (VTI) & Anna-Lisa Osvalder (Chalmers)

AHFE 2023: *14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences.* San Francisco, 20-23 July, 2023.
https://openaccess.cms-conferences.org

Presentation 1: AHFE Conference, USA 2023

Enhancing professional education through technology – a joint research approach regarding usage of eye-tracking in maritime pilot simulator training

Anna-Lisa Osvalder, Chalmers university of Technology, Sweden

The Swedish Maritime Administration provides maritime pilotage when vessels operate in Swedish pilotage-obliged water. Through the maritime pilot's knowledge of the waterways and experience of maneuvering different types of vessels, the pilot contributes to ensure that maritime and environmental safety as well as accessibility can be maintained. In addition to skills in ship maneuvering, navigation and seamanship, the ability to interact with various types of technology, cultures and crews is also required. Each ship is unique in terms of propulsion, steering, navigation, and communication equipment as well as maneuvering and information instruments. With increased levels of automation, the demands on maritime pilots to interpret, understand and handle technology are increasing. Today, the maritime pilot training is based on a long tradition of apprenticeship, where the pilot's competence can be seen as implicit (tacit) knowledge developed through years of experience at sea. But, since the maritime pilot profession is a practice in change, it puts higher demands on the pilot training. One step is to find out the experienced maritime pilots' valuable tacit knowledge and transfer this to the next generation. Another step is to include new technology in teaching activities, such as using eye-tracking in simulator training. The purpose of this multidisciplinary research project was to investigate what it means to be a professionally competent maritime pilot, and how current training practitioners are organized for pilot students to develop professional competence. But also, how the training can be further developed to achieve improved quality.

The following research questions have been addressed in four studies:
(a) What are the strengths and weaknesses of today's simulator maritime pilot training?
Study 1: Mapping strengths, weaknesses, and challenges in today's pilot training. Special focus was on exploring aspects of the pilot's tacit knowledge.
(b) What methods can be used to find tacit knowledge and visual expertise from experienced pilots useful in the pilot training?
Study 2: How the pilot's visual expertise develops within and through social interaction during simulator-based activities in the pilot training. If and how is the simulator environment a realistic and relevant training context for pilots.
(c) What didactic methods and technical support can be used to transfer tacit knowledge and visual expertise efficiently and reliably from experienced pilots to pilot students?
Study 3: Exploration of eye movement patterns between experienced pilots and pilot students.
(d) What needs for technical and didactical competence development do instructors require when implementing new technology in the pilot training?
Study 4: Evaluation of how instructors can interpret and use data from eye-tracking as a basis for training and assessment of pilot students.

The results from the research project have contributed to an increased understanding of how challenges and opportunities in today's maritime pilot training can be met with the help of new didactical and technical approaches in simulator training. The project has also generated recommendations and measures for how professional knowledge can be trained and assessed through participation in simulator environments.

Presentation 2: AHFE Conference, USA 2023

The ambiguous nature of visual expertise - Insights from using eye-tracking data for video-stimulated reflection in maritime piloting

Andreas Edvall, Swedish Maritime Administration, Sweden
Charlott Sellberg, University of Gothenburg, Sweden
Elin Nordenström, University of Gothenburg, Sweden

Abstract

In a recent meta-review of the literature on how eye-tracking technology is used and conceptualized in simulator-based training and assessment Sellberg et al. (2022, p. 319) show how eye-tracking is widely appreciated as "a method for valid, reliable, and objective assessment of proficiency". In the suggested conference presentation, we aim to challenge this view by exploring how and why eye-tracking data is relying on the domain-specific interpretations of professionals in a particular field (see Schindler & Lilienthal, 2017). The study is based on three hours of video-recorded and fully transcribed data from a focus group interview. The focus group was led by an expert on maritime piloting and an educational researcher and included six experts on maritime piloting who collaboratively viewed and discussed eye-tracking data from a simulator-based task of maritime piloting. Theoretically, we base our analysis on recent theories on the development of *visual expertise*, i.e., the "superior performance of professionals in processing domain-specific visual information" (Gegenfurtner et al. 2022, p. 3). In particular, we adopt a view of visual expertise as a complex and multi-layered system of conceptual, methodological, and technical knowledge (Lehtinen et al. 2020). The following research questions are addressed: a) how do experts interpret eye-tracking data from a visually demanding piloting task? b) what kinds of dilemmas are articulated as a result of the experts' interpretations of eye-tracking data? Preliminary analyses of the interview data show that the experts draw heavily on their professional knowledge to recognize patterns in the eye-tracking data and relate these patterns to certain navigational methods. A reoccurring theme in the discussions is the ambiguity of determining whether best practice in piloting is dependent on gaze patterns since there are several navigational methods that can be successful at any given time. Moreover, the time spent looking at visual landmarks or instruments was discussed as especially difficult to interpret, since the possible reasons behind dwell times can vary. As a result, we argue for adopting a more nuanced and critical approach to implementing eye-tracking technology to support training and assessment. Although eye-tracking technologies offers stable representations of gaze behavior which in turn makes practices of looking accountable and assessable, the method still leaves us searching for an assessment method of proficiency that is "valid, reliable and objective" (cf. Sellberg et al. 2022).

Presentation 3: AHFE Conference, USA 2023

Applied Cognitive Task Analysis (ACTA) of Marine Piloting in a Swedish Context

Cecilia Berlin, Chalmers university of Technology, Sweden
Gesa Praetorius, Swedish National Road and Transport Institute, Sweden

The Modern-day marine pilots are a competent and experienced workforce. They are highly skilled navigators that support the merchant fleet in transiting through challenging sea areas and rivers, as well as in the navigation in and out of ports. In this study, Applied Cognitive Task Analysis (ACTA) was used to pursue a deeper understanding of expertise and tacit or procedural knowledge that experts rely on and exhibit, mostly in safety-critical situations. ACTA is a structured interview method, which relies on three distinct phases: a task diagram, a knowledge audit, and a simulation interview.

In this article, results from the first two interview steps are presented to show the intricate complexity of pilotage and building blocks of expertise within marine pilotage. A total of eight experienced pilots from two different port areas in Sweden were interviewed. The results show that there are large differences in how pilotage is conducted in the two areas with regards to both tasks, knowledge and understanding of the service as such. Further, despite recognizing maneuvering as cognitively demanding, the pilots emphasized social skills and learning on the job as key elements of expertise.

Conclusions drawn from the ACTA structure highlight the mentally and socially complex task that piloting is, and that the pilots use great discernment and acuity when processing verbal and non-verbal input, as well as physical human and vessel movements.

Keywords: Transportation, Maritime human factors, Maritime safety, Cognitive task analysis

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Applied Cognitive Task Analysis (ACTA) of marine piloting in a Swedish Context

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ACTA (Applied Cognitive Task Analysis) of marine piloting in a Swedish Context

Cecilia Berlin | CHALMERS University of Technology

Gesa Praetorius | Swedish National Road and Transport Institute (VTI)

Project **"Evaluation of eye-tracking as support in simulator training for maritime pilots"** (TRV2019/117837), funded by the Swedish Transport Administration

Adapted version of the Applied Cognitive Task Analysis (ACTA) framework

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Phase 1 – Task Diagram (audio rec.)

Establish an overall, high-level description of the task at hand, 3-7 sequential steps

Phase 2 – Knowledge audit (audio rec.)

Explores specific sub-tasks that the participant considers mentally demanding

Phase 3 – Simulation Interview (audio & video rec.)

Takes the participant through a simulated task, asking what course of action they would take based on available information

Used "mediating objects"

[Task at hand]		
Aspects of expertise	a) Cues and strategies (how is the need discovered?)	b) Why difficult? (what can make execution difficult?)
Past and Futu... (predicting the chain... even...		
Big pictu...		
Noticing cues a... patte...		
Job sma...		
Opportuniti... Improvis...		
Self-monitori...		

Figure 1: Visual matrix

Maneuvering to berth				
Steps (events where evaluation or decision-making occurs)	Wh...	What is your		Possible mistakes

Figure 2: Visual ma...

Figure 3: Example of video documentation in the Simulation Interview stage

Participants

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	West coast / Area 1	East coast /Area 2
Men / Women	3 / 1	3 / 1
Age range	41 - 59	43 - 48
Certification level	SS1, SS3, SS4, SS4	SS1, SS4, SS5, SS5
Seafaring Experience (years)	17* – 27	10 - 28
Pilotage Experience (years)	4 - 25	1 - 14

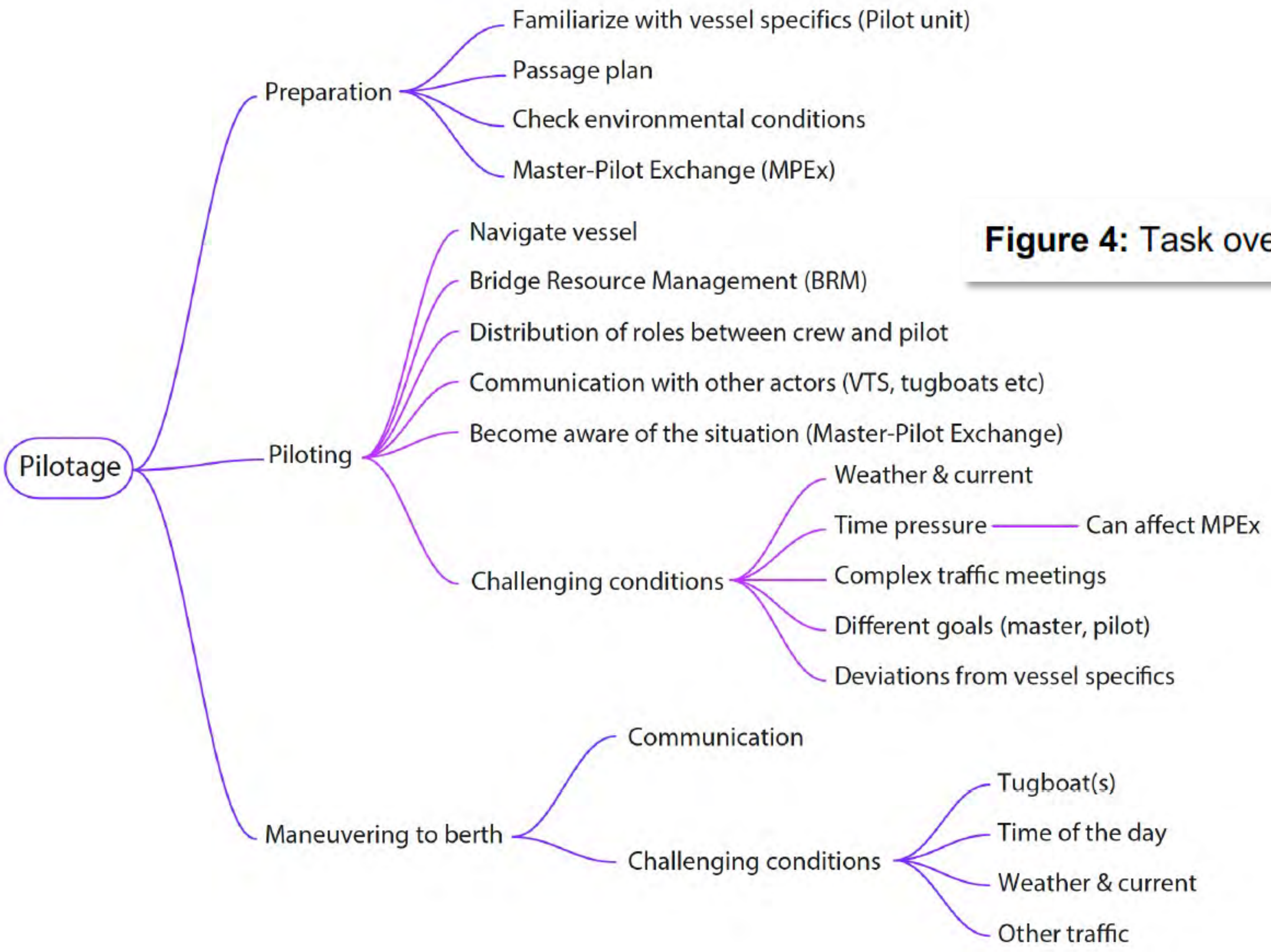

Figure 4: Task overview for pilotage in area 1

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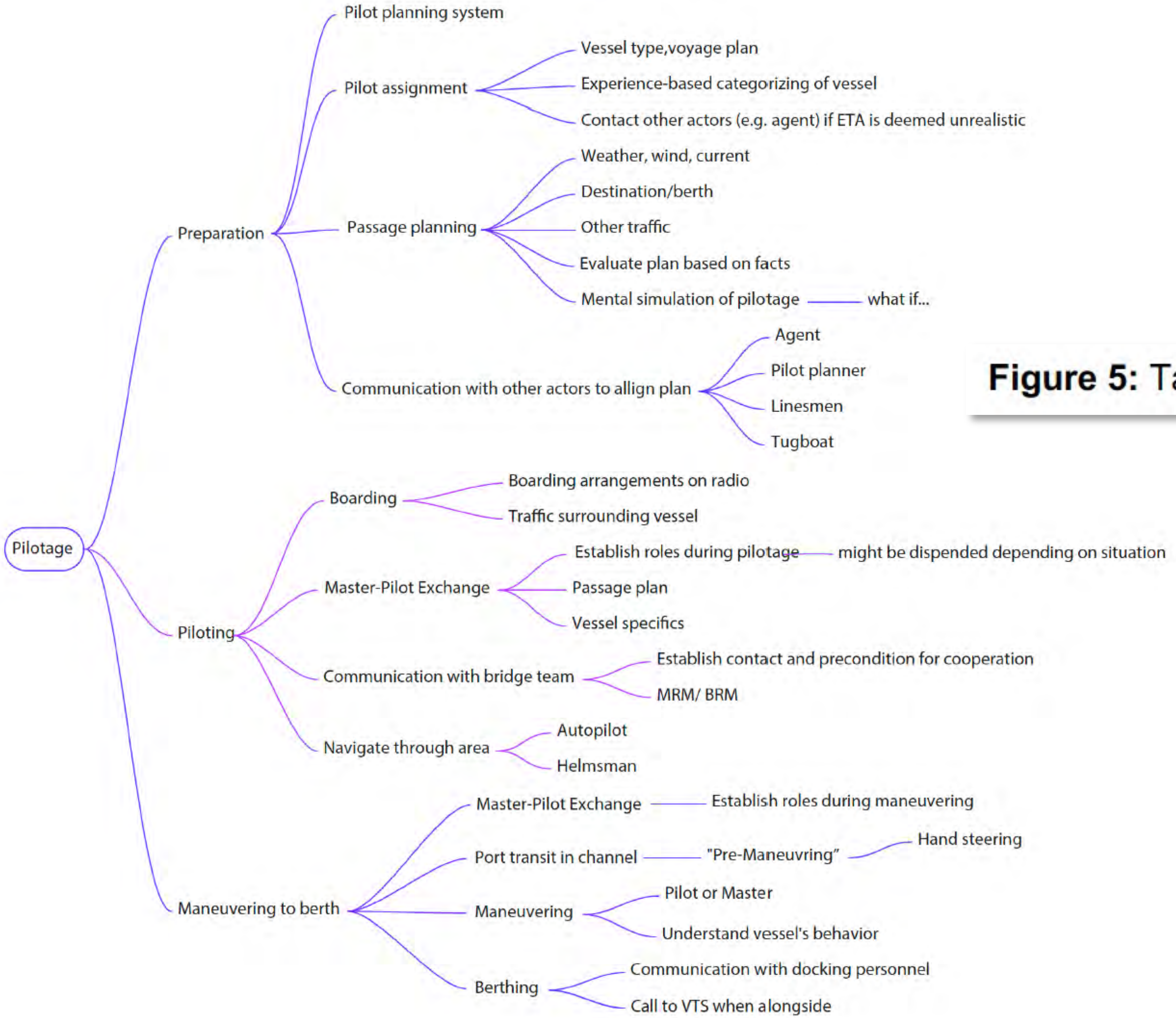

Figure 5: Task overview for pilotage in area 2

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Knowledge audit

- 6 out of 8 pilots identified maneuvering as the most cognitively demanding task
  - **Maneuvering** requires an intricate mixture of skills that are:
    - **Technical** (understanding the vessel movements and impacts of weather and currents)
    - **Non-technical** (communication, decision making and establishing leadership in the team) throughout the task
  - SMEs emphasize the need to be flexible in the light of sudden changes – no pilotage is like another
- 1 respondent focused on dealing with machine failure, and 1 the preparation, or pre-maneuvering, phase

Knowledge audit

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Predicting chain of events and having the big picture

Important for pilots to build a repertoire of vessel types, weather conditions, and social interactions with different crews to be able to quickly adapt to conditions

Job smarts, routines, planning and improvising

Pilots highlight the importance of conceiving several alternate plans to be able to adapt and act quickly when circumstances for the operation change

Knowledge audit

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Cues and self-monitoring

- Visual and proprioceptive cues from the pilot tablet, the bridge system or in the external environment
- Verbalizing the passage plan during the MPEx allows for self-monitoring and monitoring of the bridge team
- Roles that pilots must be able to take on:
  - support to the bridge team, monitoring their actions
  - actively taking control within the navigation by providing instructions

Discussion (1)

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- Importance of operational experience and knowledge transfer through interpersonal and informal learning
- Difficult to draw conclusions about how to improve formalized pilot training and education
- Pilotage expertise is built on the job
- Can be used during the preparation phase of a pilotage; enables quick adaptions and the ability to foresee potential needs for corrections

Discussion (2)

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- Difficulties with using ACTA probes on a profession that is constantly shifting in response to weather, vessel peculiarities and the state of the crew
- Safety-criticality of pilotage is not event-based, but rather dependent on constant monitoring and adaptability to shifting conditions
- Pilots were unsure whether to call any behaviour a ”job smart” or “trick of the trade”
- No two pilotage situations are alike, even within the same port

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Conclusions

- Piloting is a very mentally and socially complex task
- Pilots use great discernment and acuity when processing verbal and non-verbal input
- The expertise gained on the job is difficult to transfer to simulation-based training

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Presentation 4: AHFE Conference, USA 2023

Transferring Tacit Knowledge in Safety-Critical Systems – Examples from maritime pilot training

Rikard Eklund & Anna-Lisa Osvalder
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In safety-critical systems the complexity and the required skills to manage these systems are challenging. The consequences of errors in such systems can be disastrous. Accurate knowledge management is therefore vital for a safety-critical organization to reach set goals. Managing explicit knowledge is relatively easy but managing tacit (implicit) knowledge is much more difficult to achieve. Expert knowledge in the form of tacit knowledge can be problematic to manage in terms of elicitation, documentation, and transfer, both on individual as well as on group level. An effective transfer process for tacit knowledge between experts and novices is therefore essential. Maritime pilotage is a safety-critical operation in which pilots use their expertise to guide vessels in specific waterways. Maritime pilot training is conducted in classrooms, simulators, and in various real-life environments, often in social settings. Tacit knowledge transfer is in general dependent on situated learning, such as community of practice, apprenticeship, or hands-on learning in the social settings. Thus, different didactical methods and instruments need to be applied to assure the best learning outcome. Learning a new skill is much about reproducing existing expert knowledge in the mind of the novice pilot. However, pilot students are already expert mariners and must not only attain new skills to act as an indirect crew member of a piloted vessel, but also to maintain their expertise to provide guidance to other vessel crews. Much of the trade specific skills are acquired during the hands-on learning segment of the training, where the student interacts with a supervisor during actual pilotage on a specific waterway. Briefings before, during, and after simulator sessions are other important nodes for transferring tacit knowledge. During briefings, individually between instructor and student, or in group settings, tacit knowledge can more easily be adopted due to interaction effects when focusing on solving the same task to reach set goals. The simulator itself can also provide means for the instructor to show, and for the students to try, different approaches to achieve effective pilotage. The simulator cannot, however, solely comprise an effective didactical instrument but needs to be operated according to a quality assured syllabus. To conclude, tacit knowledge transfer is largely dependent on the personal didactical technique or style of the individual instructor and is difficult to adequately document in didactical or pedagogical terms. Furthermore, only trying to document and store tacit knowledge is not sufficient in terms of knowledge management. Reproducing knowledge requires an effective transfer process to assure that expected learning outcomes are reached. In other words, tacit knowledge must not only be transferred, but also correctly comprehended, stored, and applied by the novice pilot in the new profession. Therefore, further studies are needed to deepen the understanding on how knowledge transfer and learning outcome are linked.

Transferring Tacit Knowledge in Safety-Critical Systems
Examples from maritime pilot training

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Purpose and aim

Purpose

- Identify ways to improve maritime pilot training to mitigate increasing requirements for safe, economical and environmentally sustainable shipping in Swedish territorial waters

Aim

- Describe prevailing methods of tacit knowledge transfer during different elements in the Pilot Training Programme
- Provide suggestions on improvements of tacit knowledge transfer

Maritime piloting – A safety critical operation

- Maritime pilots use their expertise to guide vessels in specific waterways
- In safety-critical systems the complexity and the required skills to manage these systems are challenging
- The consequences of errors can be disastrous
- Accurate knowledge management is vital for a safety-critical organization to reach set goals

Explicit and implicit knowledge transfer

- Managing explicit knowledge is relatively easy but managing tacit (implicit) knowledge is more difficult
- Expert tacit knowledge can be problematic to manage in terms of elicitation, documentation, and transfer, on individual as well as on group level
- An effective transfer process of tacit knowledge between experts and novices is essential
- Different didactical methods need to be identified and applied
- Tacit knowledge transfer is dependent on situated learning, such as community of practice, apprenticeship, or hands-on learning in social settings

Maritime piloting – training

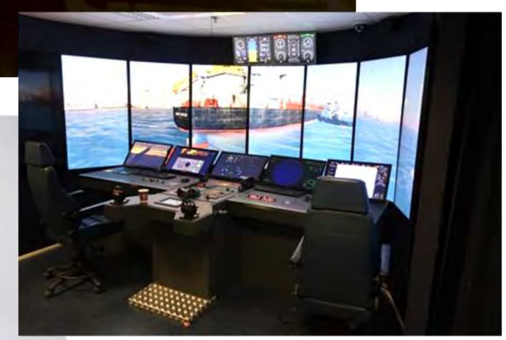
- Pilot students are already expert mariners – but as a pilot they need to train to provide guidance to other vessel crews
- Basic pilot training for 1-2 years
- Conducted in classrooms, simulators, and in various real-life maritime environments, often in social settings
- Learning a new skill is to reproduce the expert's existing knowledge into the mind of the novice pilot
- Much of the student's specific skills are acquired when the student interacts with a supervisor during actual pilotage on a specific waterway

Methodology to identify tacit knowledge transfer

Mixed-methods

- Observations
- Interviews
- Questionnaires
- Document analyses

- Eye-tracking technology
- Live-stream and recordings, data collected for analyses



Results – tacit knowledge transfer

- Briefings before, during, and after simulator sessions are important nodes of transferring tacit knowledge
- During briefings - individually between instructor and student, or in group settings - tacit knowledge can more easily be adopted due to interaction effects when focusing on solving the same task
- The simulator provide means for the instructor to show, and for the students to try, different approaches to achieve effective pilotage
- The simulator cannot solely comprise an effective didactical instrument - needs to be operated according to a set syllabus

Results – tacit knowledge transfer

- It is difficult to adequately document in didactical or pedagogical terms
- Documenting and storing tacit knowledge is not sufficient in terms of knowledge transfer but requires an effective transfer process
- Tacit knowledge transfer is largely dependent on the personal didactical technique or style of the individual instructor
- Further studies are needed to deepen the understanding on how knowledge transfer and learning outcome are linked

Conclusion

- Improved understanding of *where, when, and how* tacit knowledge is transferred provide opportunities to improve the transfer in terms of efficiency, pedagogics, and didactics

- Maritime pilot training is dependent on situated learning – with focus on the social situation containing in the specific piloting environments (e.g. pilot station, piloted ship, simulator)

- Competence (applied knowledge) is constructed in cooperation with fellow students and experienced pilots

Conclusion

- Domain specific procedures, techniques, tactics, norms, and problem solving are constructed during all phases of the maritime pilot training
- Eye-tracking technology can be used as a didactical tool to improve maritime pilot training and to evaluate tacit knowledge transfer

Presentation 5: AHFE Conference, USA 2023

Expertise and implication for technology-enhanced assessment in professional training

Charlott Sellberg, Gesa Praetorius, Anna-Lisa Osvalder

This presentation aims to summarize the presentations from the invited panel “Eye-Tracking as Instructor Support in Professional Education and Training – Findings from a Cooperation Between Research and Practice” by outlining a situated perspective on expertise, visual expertise, and the tacit dimensions of *knowing how*. We are taking the departure in British philosopher Gilbert Ryle’s definition of expertise as a form of skilled performance that is acquired through practice and experience, rather than through innate ability or theoretical understanding (Ryle, 2009). In Ryle’s view, mental states and processes should be understood in terms of the ways in which they are manifested in behavior and language. In this way, expertise is seen as a practical ability that is demonstrated through the successful performance of certain tasks, or the application of specific knowledge in concrete situations. In a similar vein, we adopt a situated perspective on the expert’s superior performance in processing domain-specific visual information. We outline visual expertise as a multi-layered system of conceptual, methodological, and technical knowledge in line with Lehtinen et al. (2020), and acknowledge how it can be demonstrated and articulated in the specific circumstances of professional work (Goodwin, 1994). In this view, simulators are a valuable recourse for the assessment of expertise in professional training since simulators offer a work relevant context for expertise to be demonstrated and articulated. However, the assessment of expertise is complicated since expertise also involves a tacit dimension that contributes to successful performance (Ryle, 2009). Tacit knowledge might include the ability to anticipate problems, the ability to make quick and accurate decisions, and adjusts to changing circumstances based on the expert’s ability to interpret subtle nuances or changes in the environment (Polanyi & Sen, 2009). These tacit dimensions of expertise are often difficult to articulate or teach explicitly, but they are an essential part of what makes an expert performer truly proficient in their field. While eye-tracking, at least initially, seems to offer a fruitful approach to explicate otherwise tacit dimensions of expertise, the technology still leaves us looking for a technology enhanced method for transferring tacit knowledge to the next generation of experts. Part of this problem might be what Polanyi describes as *part-to-whole interdwelling*, that is, that the various parts or components of a system or phenomenon cannot be understood in isolation from one another, but must be viewed in relation to the whole (Pylyani & Sen, 2009). In relation to this, dwell times when using eye-tracking technology are especially difficult to interpret, since dwelling can be a sign of both expertise and incompetence. To be socialized into the profession through the involvement in work relevant tasks and contexts, is still the most fruitful method of transferring expertise to the next generation of experts.

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Expertise and implication for technology-enhanced assessment in professional training

Charlott Sellberg, Gesa Praetorius, Anna-Lisa Osvalder

A practice-based view on visual expertise

- Skilled performance that is acquired through practice and experience
- Understood in terms of the ways in which they are manifested in behavior and language
- Practical ability that is demonstrated through the successful performance of certain tasks, or the application of specific knowledge in concrete situations
- A multi-layered system of conceptual, methodological and technical knowing-how

A tacit dimension

- The expert's ability to interpret subtle nuances or changes in the environment
  - The ability to anticipate problems
  - The ability to make quick and accurate decisions

Technology-enhanced assessments

- Simulators offer a work relevant context for expertise to be demonstrated and articulated
- Eye-tracking data offers detailed information of gaze behaviour
- However, detailed data still leaves expert’s tacit knowledge left in the tacit dimension
- To be socialized into the profession through the involvement in work relevant tasks and contexts, is still the most fruitful method of transferring expertise to the next generation of experts.

Research Project TRV: 2019/117837
2020-2023

Evaluation of eye-tracking as support in simulator training for maritime pilots

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