Differences in Workload of Both Skippers and Pilots Due to Changes in Environmental Bank Lights

Wendie Uitterhoeve and Melcher Zeilstra

Maritime Research Institute Netherlands (MARIN)
P.O. Box 28, NL-6700 AA Wageningen, The Netherlands

Intergo bv, Human factors and ergonomics
P.O. Box 19218, NL-3501 DE Utrecht, The Netherlands

ABSTRACT

In the case a sea harbour is located in an inland area, seagoing vessels have to sail a part of their journey in inland waterways. On these approach channels the inland water regulation prescribes specific bridge equipment. Inland vessels fulfil this regulation, the seagoing vessels not, but get dispensation with a pilot on board. The question arises how differences in working strategy (resulting from different ship characteristics and equipment) express in differences in workload. The effect of changes in environmental bank lights (puddle lights) on both inland skippers and pilots is studied in a manoeuvring simulator using physiological workload measurements. Event analysis is based on a combination of analytical indicators (distance between vessels) and cognitive processes like interpreting perceived visual information. Results demonstrated that the effect of changes in puddle light is different for skippers and pilots. Differences in vessel and bridge settings are indeed expressed in working strategy and result in differences in workload. Inland skippers give effort to continuous steering corrections and are, compared to the pilots, less used to anticipate on future actions. In the absence of puddle light, the skippers mental spare capacity decreases clearly. Although the subjective opinion of the pilots indicate an increase of demand, the objective measures do not show a considerable increase.

Keywords: workload, cognitive research, physiological measurements, manoeuvring simulator

INTRODUCTION

In the situation where a sea harbour is located in an inland area, seagoing vessels have to sail part of their journey in inland waterways. Both seagoing vessels and inland water vessels sail in these approach channels. Here, the inland water regulations prevail. In The Netherlands, for instance, these regulations describe the equipment required on inland waterways. The inland vessels meet the requirements, but the seagoing vessels do not. If they have a pilot on board, however, they get dispensation. Inland and seagoing vessels, differ in vessel and bridge design as well as in on board equipment. What is the effect of these design differences on the interaction with the environmental system? What, for example, is the effect of changes in the indirect bank lights (puddle light) on both pilots and inland skippers? In a discussion about the need and benefit of puddle light at the channel border, scientific underpinning is missing. Therefore, a simulator experiment is executed to study the effect of puddle light on workload and performance for both inland skippers and pilots (using the same waterway). In this experiment both skippers and pilots sailed respectively a four-barge push convoy and a Panamax coal carrier through a channel. During the manoeuvre they twice encountered a bulk carrier. The first time at a straight part of the channel, later on in a curve.

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Research question

The effect of design differences on the method of working is a matter of common sense. But, when skippers and pilots are sailing in the same environment, how will changes within this environment effect on workload? The mean research question is what will be the effect of changes in environmental bank lights on workload and performance for both inland skippers and pilots sailing on a channel? And second. is the effect of changes in puddle light the same for skippers and pilots? Are there any differences and if so, which are they?

DIFFERENT CIRSUMSTANCES FOR SKIPPERS AND PILOTS

For the Dutch inland waterways national and additional local regulations prescribe use of radar, Rate Of Turn indicator (ROT indicator)and automatic steering. Most inland vessels have these devices on board. Sea going vessels not always. This chapter will describe how differences in vessel characteristics and available equipment at the bridge result in different sailing strategies.

Design differences

Different vessels
Table 1 shows the main particulars of the vessels used in the simulator experiment. The larger Panamax coal carrier reacts slower and is less sensitive for external changes like wind gusts. The wind forces are relatively small compared to inertia effect of the larger displacement, and do not have much effect on course stability. This is not the case for the four barge push vessel. The less favourable ratio between displacement and wind force makes that fluctuations in wind speed do have an effect on the course stability. This results for the inland skippers in more steering correction to intercept changing wind forces.

For the seagoing Panamax the location of the bridge is about three times higher than for the inland water vessel. This puts the pilot in a better position to look ahead the situation in the channel anticipate.

Table 1: main particulars of sea going and inland water vessel

	Sea going vessel	**Inland water vessel**
Type of vessel	**Panamax coal carrier**	**Four barge push convoy**
Length overall (Loa) [m]	248	193.5
Beam [m]	32.2	22.8
Draft [m]	8	0.6 (empty)
Displacement [tonnes]	50240	2350
Power [kW]	8000	2 x 1980
Bow rudders [m^2]	No	2 x 2.7
Height of bridge above water level [m]	30	8.4

Different equipment
The inland skippers use a river radar combined with a ROT indicator. This provides information about the location of the vessel and also about the forward sailing speed and lateral and rotational motions and directions. But the radar also has some limitations, viz. the information is in fact history and the contours of a vessel are deformed. Consequently, exact information about the size of other vessels and the distance of your vessel to the bank is missing. The skippers look outside to complete the picture with information from the outside environment.

On the other hand, the sea radar is in narrow water less useful. Without the presence of a ROT-indicator, the pilots use the radar mainly to keep their vessel in the middle of the fairway. The pilots need to look outside to get information about the actual vessel behaviour. They use marks like puddle lights to recognise changes in course.

Different roles
The inland skippers sail the vessel on their own. Controlling slow varying processes and responding to actual conditions in a way of executing steering actions are both tasks of the same person. The pilot has the assistance of a helmsman which makes that the pilot can focus better on the slow varying processes.

Different position at fairway
In the simulator runs with the inland skippers, the width of the channel is 160 m. Regulatory prescribes the sea going vessel to sail in the middle of the fairway. During the encounters, the skippers have to give way to the Panamax bulk carriers.

The runs with two encountering sea vessels were executed in a channel of 265 meter. This fairway was wide enough for a relative easy encounter. The pilots had to change little but could stay in the comfortable deeper fairway.

Effect of design differences

Both the more stabilised character of the vessel, the higher bridge position and the assistance of a helmsman allow a pilot a better overview of the situation. The pilots are more used to controlling the process and to preparing future actions. He is more able to anticipate than an inland skipper. Lacking appropriate equipment, the pilot detects an upcoming vessel in the environmental view. He completes an actual picture at a time.
Due to the less stabilized character of the vessel, the skipper is busier with reacting to actual disruptions and correcting effects from past actions. A shift from “now” to “future” is more difficult for the skippers. When an inland skippers detects another vessel at the radar, uncertainty arises about the real dimensions of the vessel. Apart from his steering activities, he needs to gather information from the outside view.

EXPERIMENT IN THE MANOEUVRING SIMULATOR

The goal of this experiment is to investigate the effect of changes in puddle light on the workload and performance of skippers an pilots. In this simulator setting the effect of differences in equipment can be demonstrated. Possible differences on working strategies and workload can be measured.

Experimental setting

Fairway
A representation of the modelled fairway is given in Figure 1. In this figure North is above. Two vessels sail a fixed southward track. The north going vessel is sailed by the participants. The run starts with a straight part. The first encounter takes place in the first framework. The second encounter is in the curve to the left. These locations are represented with the frameworks in Figure 1. The narrow channel is 160 m wide at the surface and 65 m at the bottom, at 13.5 m depth. The other fairway is 265 m wide at the surface and 170 m wide at the bottom, at 15 m depth.. The depth and cross section are corresponding with Kanaal Gent-Terneuzen en het Noordzeekanaal, both in The Netherlands. No artworks are modelled.

Puddle light
Three different conditions are modelled for the skippers. One without light, one with lights every 100 meter and one every 200 meter. In case of the runs with the pilots, red green isophase lights were modelled instead of white light every 200 m.

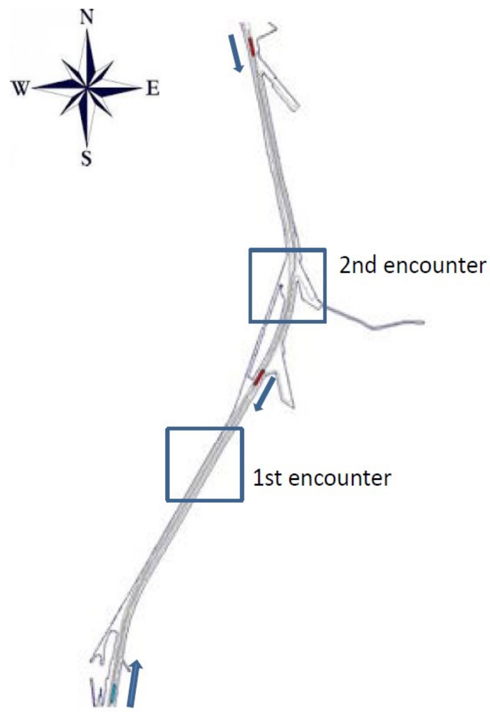


Figure 1: Representation of the fairway

Wind

Wind Beaufort 5 (mean wind speed 10 m/s) is modelled. Wind gusts are introduced by a Davenport wind spectrum. Wind shielding caused by the encountering bulk carriers is taken into account. During the encounter, the own ship sails partly in the wind shadow of the encountering bulk carrier.

Vessels

The main particulars of respectively the sea going vessel and the inland water vessel are given in Table 1. The encountering bulk carriers are respectively 225x32,3x9,3 m (160 m wide channel) and 277x42x9,1 m (265 m wide channel).

Conditions

In the inland vessel runs, executed with an 160 m width channel, three puddle light variances are modelled as given in Table 2. An additional condition with red and green isophase lights was modelled for the runs with the Panamax coal carrier sailing in a 265 wide channel.

Execution of simulations

The simulations are executed during two sessions of both three days. During the first session six experienced push barge skippers sailed. Later on six experienced pilots visited the simulator. Every day two candidates started with a briefing and familiarisation run and alternately sailed one of the conditions. Every condition is repeated by 5 skippers or pilots see Table 2. To avoid any learning effect, the conditions are randomly divided over the participants.

Table 2: Overview of different conditions

Condition	Channel width	vessel	Puddle light	Amount of repetition (candidates)
A	160 m	Four barge push convoy	None	5 (S1,S3,S4,S5,S6)
B	160 m	Four barge push convoy	White, every 100 m	5 (S1,S2,S4,S5,S6)
C	160 m	Four barge push convoy	White, every 200 m	5 (S1,S2,S3,S5,S6)
F	265 m	Panamax Coal carrier	None	5 (P1,P2,P4,P5,P6)
G	265 m	Panamax Coal carrier	White, every 100 m	5 (P1,P2,P3,P4,P5)
I	265 m	Panamax Coal carrier	Red/green, every 200 m	5 (P2,P3,P4,P5,P6)

Methodology

To measure workload and performance in a simulator training setting, a methodology that combines workload and performance measurements with a secondary task performance is being used [Uitterhoeve, 2012].

Workload

Assuming that no single parameter could indicate workload and that reliability increases as more indicators point out the same, several parameters are obtained [De Waard, 1996]. For subjective effort rating the RSME developed by Zijlstra [Zijlstra and Van Doorn, 1985] is used. This rating scale runs from 0 to 150 and contains levels from "absolutely no effort" till more than "extreme effort". The candidate puts a mark on this scale.

Objective heartbeat measurements are recorded with Co2ntrol equipment (Decon Medical Systems, Weesp, The Netherlands). An elastic belt around the chest of the trainee contains a device to record the heartbeat and determines inter beat periods (RR).

To measure focus on the main task, a peripheral detection task is added. The secondary task applied in the experiment consists of reacting to a red flash light in the peripheral view of the candidate. The reaction time and missed stimuli are the indicators for spare mental capacity [Martens, 2000].

Performance

The simulator delivers several time traces. In this experiment time traces of rudder angle, distance to the starboard border and distance to the encountering bulk carriers are taken into account. An overall interpretation of the workload and simulator data provides additional information about cause and effect. The focus of this paper is on workload. Therefore, the quality of the performance during the run is outside this field of attention.

Figure 2: Candidate wears the secondary task helmet (left), RSME (middle), impression of experimental setting (right).

Procedure

Before the start of the first run, candidates were briefed and prepared to the test. This comprises putting on the heartbeat belt and the PDT equipment and checking the wireless connection of both systems. The heart rate and secondary task were measured during the total run, approximately 30 minutes. The RSME score is filled in twice; first during the simulation directly after the first encounter and second directly after the run. The runs stopped when a stable situation after the second encounter was reached. Stable in this case means that the vessel is back on its original track and that lateral movements are minimized. This was most of the times within a few minutes after the second encounter.

Data analysis

Analysis boundaries

In first instance, the data analysis was executed with the use of three predefined analysis windows within the time trace. These intervals were related to sailing at a straight part of the channel and the two encounters. These intervals are easy to define based on the simulator output. But in this quite mathematical analysis any relation with the impact of the manoeuvre on the operator is missing. Involving also the heartbeat and secondary task in the time traces analysis, resulted in 6 intervals based on events and cognitive processes like interpreting perceived visual information. During the first interval, the candidate spots the encountering vessel. For the inland skippers, this window is related to the moment that the bulk carrier appeared in the outside view. Thanks to the lessons learned from the skippers' experiment, the pilots were asked to indicate the moment they detected the bulk carriers. This results in a more truthful definition of the interval. The second interval represents the preparation of the encounter. The criteria for this interval are related to changes in rudder actions and distance to the border. The third interval is based on the encounter itself and is determined based on the relative distance of the two vessels. This set of three windows in repeated for the second encounter. So window four, five and six represent respectively detecting the second vessel, preparing and executing the second encounter. Figure 3 illustrates both the three and six intervals for the same run.

In the 6 window analysis, the intervals are shorter and more concentrated to the moments of interest. Consequently, mean values can be higher or lower compared to the mean values obtained from the wider intervals from the 3 window analysis. In the latter case, the wider window represents more than just the moment of interest. The mean value is more smoothed out. The effect of the interval length is visible from a comparison of plots in Figure 4 till 7.

Workload indicators

Every run delivers two subjective rating values (RSME score), one per encounter. A higher value indicates more effort needed to fulfil the task.

For the secondary task both the average reaction time and the average percentage of missed stimuli over the time window are calculated. More attention to the main task results in more missed samples and a higher reaction time. This corresponds with less mental spare capacity available for additional tasks.

The Energy Control software belonging to the Co2ntrol system expresses a combination of heart rate (RR) and breath frequency in a parameter called “amplitude”. The difference between the maximum and minimum RR within one breath cycle is calculated as a moving average. This “amplitude” is taken into account in the event analysis. According to the software manual, a lower “amplitude” means less RR variation and indicates more workload.
The mean heart rate per window is calculated. An increase in heart rate can indicate more physical or mental demand [Jorna, 1993]. During the run, the physical demand is low and constant. Therefore, significant changes can be related to mental demand.

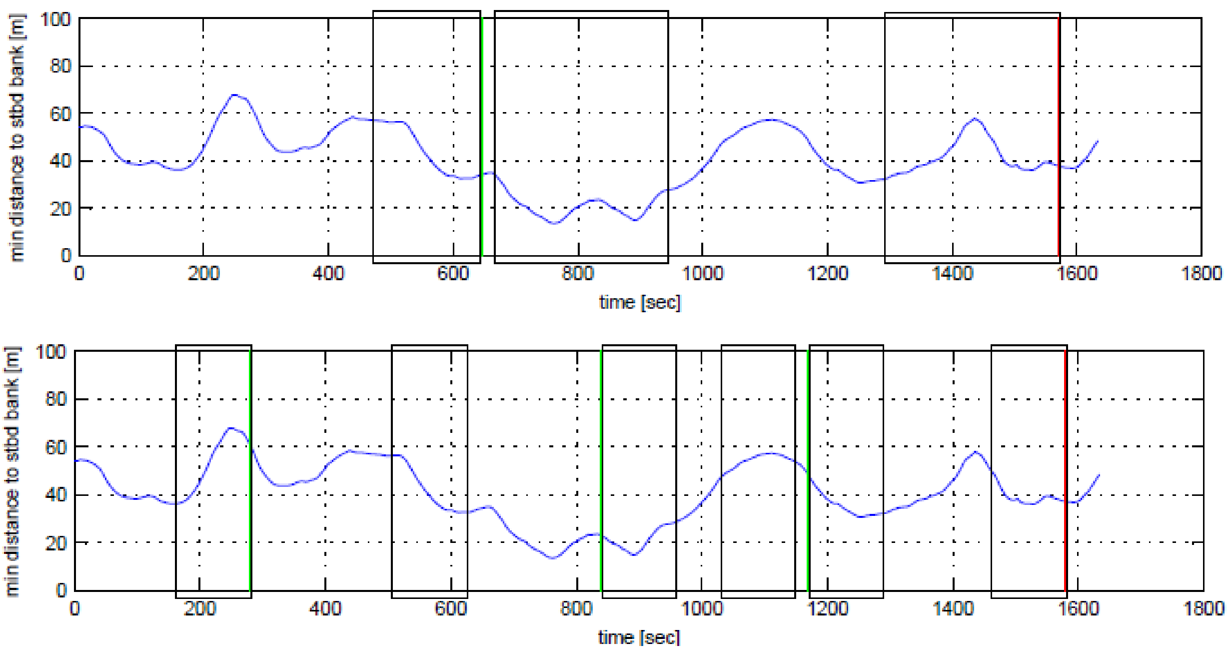


Figure 3: Example of 3 (above) and 6 (below) window analysis for the same run. The x-axis represents the time (s), the Y-axis represents, as an example, the minimum distance to the starboard border (m).

A specific HRV analysis is executed with the aid of KUBIOS software developed by the Biosignal Analysis and Medical Imaging Group of the University of Eastern Finland. KUBIOS analysis is based on the heart rate variability guidelines (Malik, 1996). After filtering outliers in the RR time trace, a spectral analysis is executed. Parts of the spectrum are related to activity of the autonomic nervous system. The ratio between sympathetic (related to stress) and parasympathetic (related to relaxation) activity is expressed in the so called LF/HF ratio. A higher LF/HF values means more sympathetic activity (as a result of increased demand for example) [Tarvainen, 2008].

For each window per run the average value of the workload and performance indicators is calculated. Per condition these mean values are averaged, see Table 3. These mean values are plotted in graphs, both for the three and six window analysis, see Figures 4 to 7.

Table 3: Example of Amplitude, LF/HF and heartbeat results for condition Aand C.

		Amplitude			LF/HF			heart beat		
Scenario	Candidate	ref.part	encount1	encount2	ref.part	encount1	encount2	ref.part	encount1	encount2
A	**mean**	**50.2**	**49.8**	**49.2**	**3.1**	**4.3**	**4.6**	**77.8**	**79.1**	**78.2**
	1	80.7	77.3	69.7	2.0	4.9	2.6	73.5	70.8	72.9
	4	46.3	49.7	47.6	0.6	3.4	1.0	85.6	91.1	90.3
	5	35.5	30.5	30.6	1.6	4.4	6.5	70.3	71.5	68.4
	6	38.3	41.8	48.9	8.1	4.5	8.4	81.9	83.1	81.2
	3	56.9	81.5	82.0	12.6	10.8	12.1	85.6	85.0	86.0

RESULTS

Results of three different light conditions are presented in Figures 4 to 7. Mean values for heartbeat, subjective effort rating (RSME), secondary task performance and LF/HF are plotted. The X-axis represents the windows.

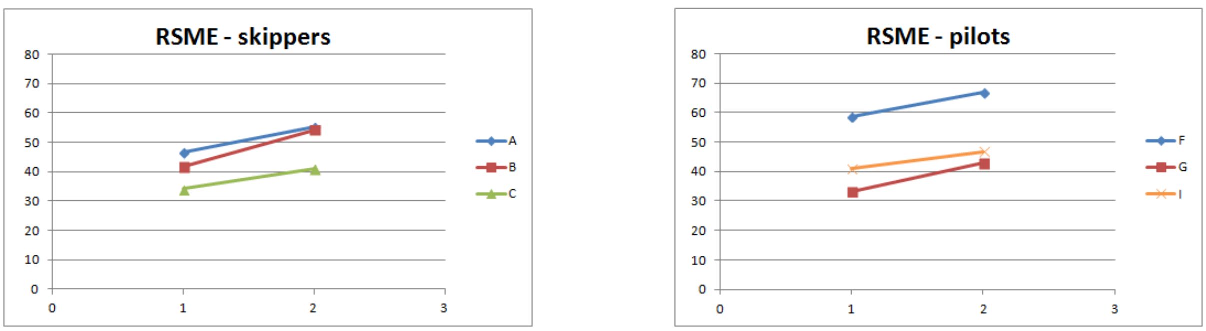
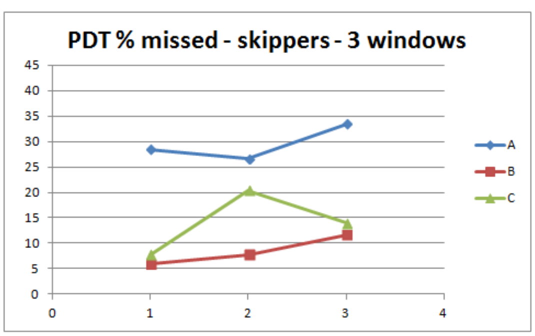
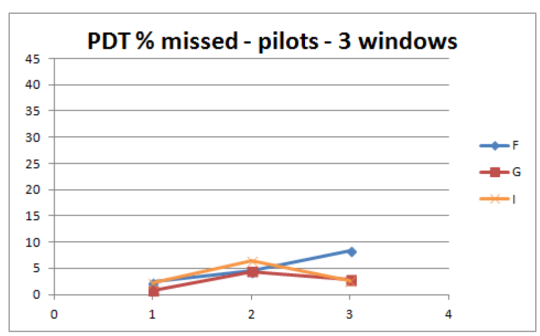


Figure 4: Mean values for subjective effort rating for inland skippers (left) and pilots (right).





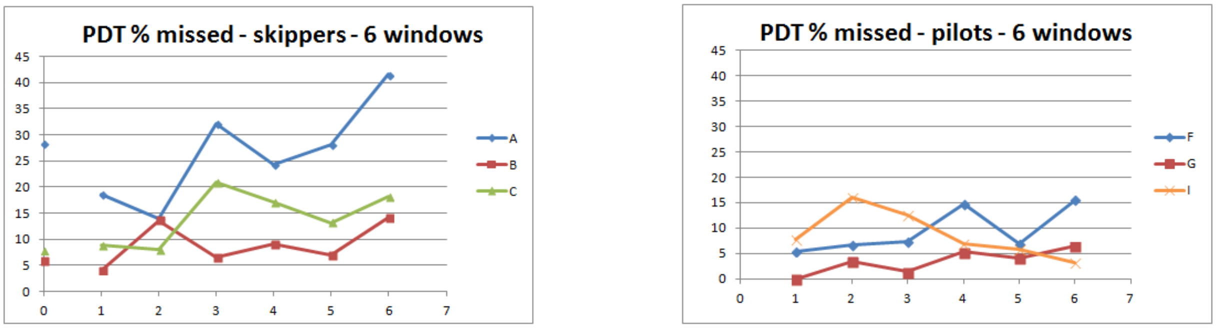


Figure 5: Mean values for % missed secondary task samples for inland skippers (left) and pilots (right).

Effect of puddle light on inland skippers

Both the secondary task and the subjective rating clearly indicate that condition A (without puddle light) is the most demanding situation. The heartbeat itself and its derivative LF/HF do not give a clue about the most demanding situation, but provide additional information about the effect of light on the impact of the encounter on the skippers. The three window analysis of heart rate and LF/HF is presented in Figure 6 and 7 (left). In the non-lighted situation (A) the mean heart rate decreases during the second encounter, while this increases in the lighted conditions (B and C). In condition A, the LF/HF is for both encounters more or less equal. In the lighted conditions the LF/HF value is much higher during the second (and more demanding) encounter. Putting these findings in the perspective of the secondary task performance and subjective rating (indicating condition A as most demanding), the physiological results indicate that the impact of the encounter in a lighted condition is larger than in a non-lighted condition. The increase in demand due to the second encounter compared to the first and more easy part of the run is relatively larger in this condition.
The more detailed six window analysis of LF/HF (Figure 7 left) shows another phenomenon. In condition A (without puddle light), a peak is visible for interval 4. This moment of increased workload is related to the moment the skipper detects the second vessel. This peak is less in condition C (every 200 m light) and absent in the most lighted condition B. This indicates that not only the encounter itself, but also the cognitive process related to the detection of the second vessel is subject to the effect of puddle light.

Effect of puddle light on pilots

In this case the physiological results are in line with the secondary task data and subjective rating. The subjective rating clearly indicates the case without lights (F) as most demanding (Figure 4). Based on the secondary task performance both case F and the red/green light condition (I) are indicated as most demanding (Figure 5). The LF/HF ratio rather fluctuates and shows higher peaks for the red/green light condition compared to a more constant LF/HF level in the condition without puddle light (F) (Figure 7). This indicates higher workload peaks alternated with moments of relaxation in condition I, and a more constant demand level with less variation in tension and relaxation in condition F. Based on heartbeat, LF/HF, RSME and secondary task, the condition without puddle lights is generally experienced as most demanding condition. The pilots overcome the negative effect of the isophase red/green light.

Red-green isophase light
The amount of missed samples in the first part of the red/green illuminated run is rather high (Fig 5 right). In the second and more difficult part of the run, the performance improves, which suggest less mental demand. But the heartbeat and RSME value don't confirm this finding. This seems paradoxical, but can be explained by the visual effect of the red green flickering light. This is very close to the effect of the red flash light from the secondary task. In the beginning of the run, the pilots have difficulty with combining both visual effects.

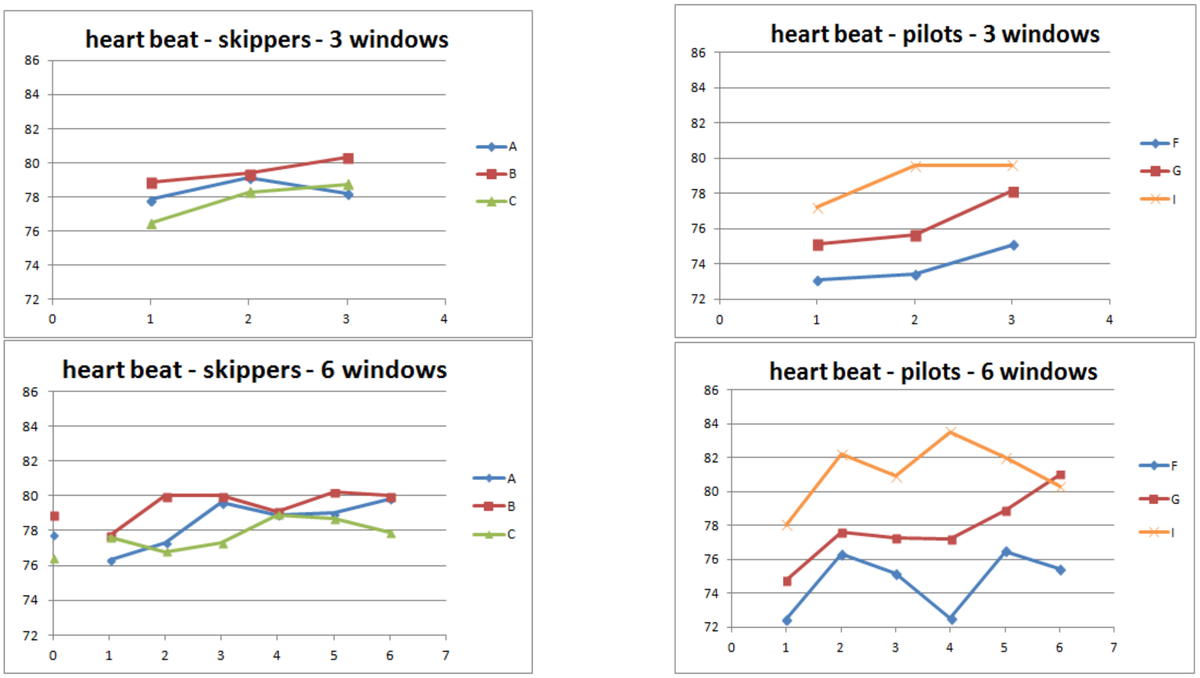


Figure 6: Mean values for heartbeat for inland skippers (left) and pilots (right).

Differences between skippers and pilots

A comparison between the skippers and pilots is made in two ways. The event analysis of individual time traces provides behavioural information and general observations are compared. On the other hand, the averaged statistical results are compared as well which gives insight in differences of general workload level for both type of sailors.

Event analysis – effect of wind gusts on workload

During the debriefing the inland skippers mentioned the wind gusts as a cause of increased workload. Nevertheless, not every wind gust resulted in increased heartbeat or decreased secondary task performance. Also, not every moment of intensive rudder actions is visible in the mentioned time traces. The simultaneously interpretation of both physiological, secondary task performance and simulator output time traces pointed out that not only one cause resulted in increased workload. It is a combination of, for example, capturing the wind coming back on the vessel after shielding by the bulk carrier while going back to the centre of the fairway.

Due to the more advantageous vessel characteristics, the larger vessel sailed by the pilots is less affected by the wind gusts. The pilots do not spent much effort on continuously correcting for wind gusts. In a combination of accumulating workload factors, the wind gusts do not play a role.

Event analysis – effect of perceiving a vessel on workload

The time traces showed for all inland skippers roughly at the same moment an increased heartbeat and decrease of secondary task performance. This was not directly related to the encounter or wind gusts (as supposed by the skippers). Apparently, the moment of perceiving the second vessel caused this increase in workload. After passing the first vessel, the skippers are still busy with controlling the vessel and correcting translational motions as a results of the encountering. The cognitive process of interpreting visual information is than an additional reason for increasing workload.

The pilots are generally more used to look forward and anticipate at future actions instead of react to something happening at the moment. Detecting a second encountering vessel was just in a few cases an additional cause for increased workload.

Event analysis – effect of encounter on workload
As expected, the workload increases during an encounter. Figures 5 till 7 (3 window analysis) show in almost all cases that the amount of percentage missed stimuli, heartbeat and LF/HF are higher in interval 2 and 3 (representing the encounters) compared to interval 1 (no encounter). The RSME scores clearly show that the second encounter is more demanding than the first one (Figure 4). This is due to the additional demand caused by curve in the channel at the location of the second encounter.

Event analysis- effect of light condition on reaction time
Not only the results within a window provide information about the effect of puddle lights on workload, also the time between the windows can be used as an indicator. The time between interval 1 and 3 and between 4 and 6 can be seen as a kind of reaction time: the time between observation of an encountering vessel and prepare the encounter. These reaction times are given in Table 4.

Table 4: Time between observe of and react to encountering vessel for skippers and pilots sailing In two light conditions

Reaction time [sec]	**First encounter**	**Second encounter**
Skipper – no light (A)	935	1635
Skipper – 100 m light (B)	1115	1005
Pilot – no light (F)	2570	2670
Pilot – 100 m light (G)	2680	2350

Due to the higher sailing speed of the inland vessel, the time between observing en reacting is shorter compared to the runs executed by the pilots. The Tables shows that the reaction time of the pilots is more or less the same in case of no light and with light every 100 meter. For the inland skippers sailing in condition A, a clearly visible increase between observe and react is shown. There can be some doubt on the moment the skipper observed the second bulk carrier, but that could only partly explain this significant increase. It seems more logical that the skipper needs more time to create a total picture of the coming encounter. In addition to the radar data, he gathers information from the environment. In the 100 m light condition, the skipper looks more outside and can easier collect all information needed.
For the pilots no real effect of puddle lights on cognitive performance is visible. To gather actual information, they have to look outside in all conditions. The absence of light does not have an effect on the pilots' time to start with the preparation of the second encounter.

Mean values – RSME
Figure 6 shows one clear outlier for the pilots condition without puddle light. In case of the skippers, the non-lighted condition differs not very much from the lighted conditions. As the skippers mentioned, they especially suffer from the wind gusts. This was the same in all conditions. Possible explanation in case of the skippers is that the effect of the wind gusts is more expressed in the RSME value than the effect of puddle lights.

Mean values - % PDT missed
According to Figure 5, the secondary task performance of the pilots is much better compared to the performance of the skippers. From the skippers' results it can be seen that in the condition without lights the primary tasks needs more mental capacity. The pilots can easily deal with this additional task and no significant distinction in light

condition is visible.

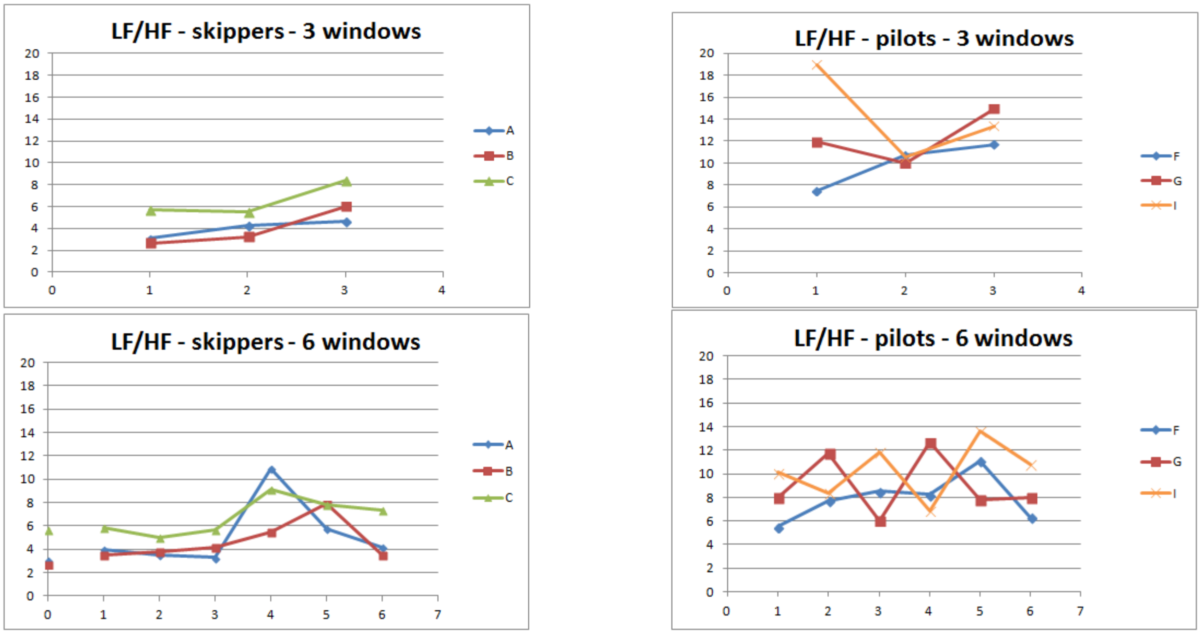


Figure 7: Mean values for LF/HF for inland skippers (left) and pilots (right).

Mean values – heartbeat

For the skippers, the variation in heartbeat is quite low (Figure 6). This is the case for the different conditions but also during the run of a condition itself . For the pilots, the variation in heartbeat during the runs is larger compared to the skippers, especially for the condition without light. This is an indication that the skippers experience a constant workload during the run and that the pilots experience more variation in workload during the run.

The pilots' heartbeat is remarkably higher during the red/green condition as for the other conditions. During the debriefing, the pilots mentioned their irritation about the flashing red and green lights. The negative emotions (irritation) is expressed in this higher heartbeat.

Mean values – LF/HF

Again, the effect of the red/green light (in the beginning of the run) is visible in the three window analysis for the pilots (Figure 7).The six window analysis shows for the pilots alternation of demanding and relaxing intervals. For the skippers , the six window analysis shows clearly that the second part of the run is more demanding than the first part. In particular peaks in windows 4 and 5 (respectively detecting and reacting) demonstrate this.

DISCUSSION AND CONCLUSION

Effect of changes in puddle lights on workload

The first research question was about the effect of changes in environmental bank lights on workload and performance for both inland skippers and pilots sailing on a channel. For both skippers and pilots, workload is increased in conditions without puddle lights. For the skippers this is particularly expressed by the secondary task performance and the heart rate measurements. In case of the pilots, the workload is increased in two conditions, expressed by the heart rate and the subjective rating. Both from a different background. The condition without puddle light is demanding because of the missing reference point in the environmental view. In the condition with the red/green isophase light the interference of flash lights and frustration about these flickering lights is mainly expressed in respectively the secondary task performance and heart rate measurements. The subjective rating indicates clearly the non-lighted condition as most demanding for the pilots.

Differences between skippers and pilots

In both experiments, the condition without puddle lights comes up as the most demanding case. But that does not automatically mean that the effect of absence of light is the same for skippers and pilots. To answer the second research question about the differences in change of workload due to changes in puddle lights, the focus is on the non-lighted condition. In this most demanding condition, the differences are more pronounced.

1. The first difference is found in the workload indicators itself. For the skippers especially the secondary task performance gives a pronounced differentiation in demanding conditions. For the pilots, these objective results are less distinctive and is the subjective RSME value the most pronounced value.
2. A second difference comes from the comparison of the secondary task results. These show that the skippers need more mental capacity for the execution of the run than that the pilots need. Especially in the second part of the run, the increased workload starts to have an effect on the skippers' cognitive process. They need more effort and time to interpret visual information and prepare the second encounter. This is demonstrated by the high LF/HF value at window 4 in combination with the larger reaction time to start the preparation of the second encounter. The pilots' results do not point out any effect of workload on cognitive processing.
3. From the subjective rating comes a third difference. The subjective rating by the pilots indicates clearly increased effort in the non-lighted run. Although it is expected that the non-lighted condition also by the skippers is experienced as most demanding, the RSME does not confirm this very clear. The most and non-lighted condition are almost equally rated. As the skippers mentioned, they mostly suffer from the wind gusts. Probably these wind gusts rather than changes in environmental bank light are the underlying factor in this rating.
4. The last difference is found in the heart rate results (LF/HF). During the whole run, the pilots clearly alternate between more and less demanding moments. This is especially seen during the lighted conditions. The skippers do not so. Their results show increased (moments of) workload during the second (and more demanding) part of the run.

These four differences create an image that shows that (during the conditions without puddle light) the general workload for the inland skippers is higher compared to the pilots.

Combination of factors

It was seen from the results that especially for the skippers workload increases when a combination of demanding factors occurs. These factors are related to design differences and available equipment at the bridge and also to events happening during the run. The skippers:

- have to correct more for disruptions due to wind gusts (as a results of the vessel characteristics),
- complete the actual picture with information from the environmental view (due to limitations of the radar
- have to give way to sea going vessels
- can, compared to the skippers, less overview the channel (due to a lower bridge)

The detection of the second encountering vessel is taken as an example. After detecting this vessel, the skippers have to gather additional information from the environmental view, as a results of the limitations of the radar. They have to do that while they are still eliminating lateral vessel motions caused by wind gusts and giving way to the first encountering vessel. In this combination the absence of light is an additional demanding factor. At the end the accumulation of factors effects the time needed to interpret visual information and prepare a second ancounter.
On the other hand, the pilots have detected the encountering vessel already in an earlier phase. The higher bridge position is benificial to this. Besides that, the environmental view provides all information about position and size of the vessel at one glance. Finally, the pilots do not suffer from wind gusts.

Task analysis

To unravel the demanding factors and study the effect of differences vessel characteristics and equipment on tasks and working strategies, a task registration is needed. Then it is possible to determine which event or task is the most leading one to increase workload and to find relations between events and tasks. Differences in working strategies can be studied and the way how they are expressed in differences in workload.

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