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NAVIGATION WITH 2-D AND 3-D MAPS – A COMPARATIVE STUDY WITH MARITIME PERSONNEL

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This paper reports on a study within the framework of the research on 3-D Nautical Charts, using an egocentric perspective of the mapped area. To study the effectiveness of the egocentric perspective we use the maze experiment used earlier by Porathe (2005). Here we validate the experiment with persons more closely connected to the maritime domain, i.e. naval officers. The results clearly point in the same direction as Porathe's earlier findings – the 3-D maps is easier to use, causes less groundings and shorter times on track than traditional navigational aids.

Navigation, 3-D Nautical Charts, ego-, exocentric view, mental rotations

1 Introduction

As we move about in our everyday life spatial awareness is constructed by a number of cues from the physical world around us. These cues are integrated in our head to what we can call our *situation awareness* (Endsley, 1995). In the maritime domain these cues could be the bearings to two different landmarks. Two such bearings will in an unambiguous way define a position on the surface of the earth. However such integration is difficult to perform in our heads. In a nautical chart the bearings could be drawn with the help of a protractor. The two bearings will intersect in a "fix" on the chart. The chart and the protractor here becomes a *cognitive tool* aiding us by doing some of the integration work for us (Hutchins, 1995). The map is the world depicted from an *exocentric* bird's eye view, while the view out of the window is an *egocentric* view. To integrate these two perspectives a *mental rotation* of the map has to be performed. Shepard and Metzler (1971) showed that these mental rotations were both time consuming and could be erroneous. Integration in the head comes with a cost; we call it the cognitive, or mental, *workload*. Modern high speed craft pushes the limits of human performance as decision times decrease. But at the same time the technological development of satellite based positioning systems has opened possibilities of having more of the integration work in navigation performed by integrated navigation systems. One such suggestion of cognitive off-loading has been presented by Porathe & Sivertun (2002). By presenting a three-dimensional chart from an egocentric point of view the navigator is offered the option of seeing the map from a perspective equivalent to the view out of the bridge windows, and by doing so removing the need of performing mental rotations. Thus some of the integration work moves from the navigator to the navigation system. To test the notion of cognitive off-loading a laboratory experiment in a maze was conducted on university students with very little experience of navigation (Porathe, 2005). The performance based measurements used were *time on track* and

number of *groundings*. The experiment showed that egocentric view navigation was more effective than traditional navigation.
The remaining question is how ecologically valid these results are. Would results from trained and experienced mariners be the same as those of the university students?

2 Objectives

To see if navigation with the use of 3-D egocentric maps makes for more efficient performance and safety than traditional 2-D exocentric maps. Here we look closer at how people from the maritime domain perform in the study. Are there differences in performance dependent of different kind of navigational experience? The results are compared with the earlier study. We also validate the maze method by comparing the data with the earlier study.

3 Method

3.1 The maze experiment

30 persons drove a small cart through a maze, logging time on track and groundings, with the help of four different maps. Each representing the maze using different visualisation techniques common for navigation. These were a paper map (no position given), a map displayed in "north-up" (own position given), and a map displayed in "head-up" (own position given). All these three map types uses the traditional exocentric perspective, or the bird's eye view. The fourth map type was the 3-D map with the egocentric perspective (see Figure 1). Each person drove with each type of map once through the maze, which was set up differently each time. The implementation was the same as Porathe (2005).

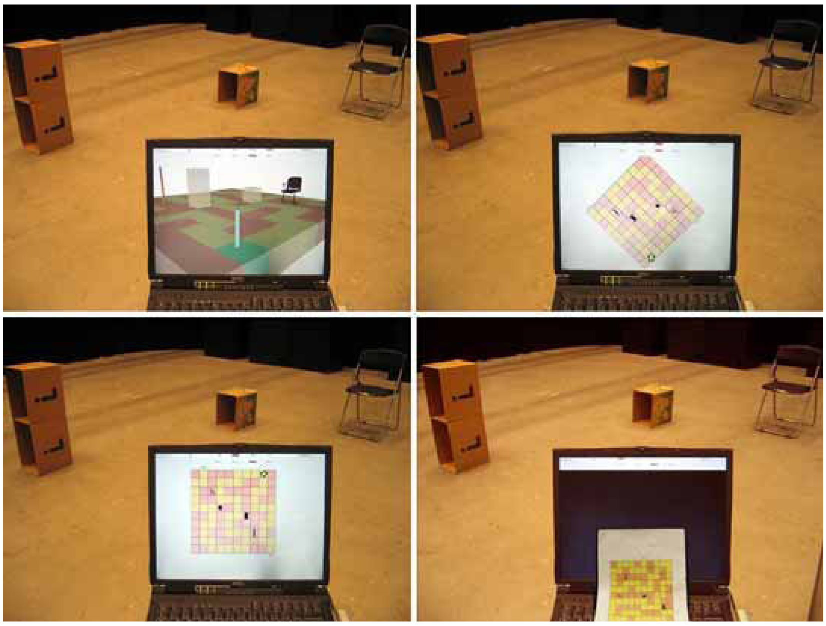

Figure 1. Picture from the experiment setting showing the four different map types.

3.2 Test subjects

All test subjects answered a questionnaire concerning their navigational experience. Examples of questions are: time at sea in an active navigating role, type of ship etc. This made it possible to subdivide the subjects into groups. Of the 30 test subjects 18 were categorised as high-speed navigators, all of them with a background as Combat craft officers in the Swedish Navy, navigating small craft at 40 knots of speed, in restricted waters. 6 of the test subjects were categorised as experienced bridge officers from the merchant navy and 6 were cadets on their final term at the naval academy.

4 Results

The results indicate that navigating through the maze with the help of the 3-D map was the most efficient both concerning time on track and groundings. The mean time for all 30 participants was 122,9 seconds (s) and 1,6 groundings (gr) for the 3-D map. Second most efficient was the head-up map with a mean time of 142,0 (s) and 2,5 (gr). Ranked third was the map used in north-up with an average time of 156,3 (s) and 3,1 (gr). Fourth and the least efficient navigation tool through the maze was using the traditional paper map with 192,8 (s) time on track and 5,8 (gr). The results are presented in Figure 2.

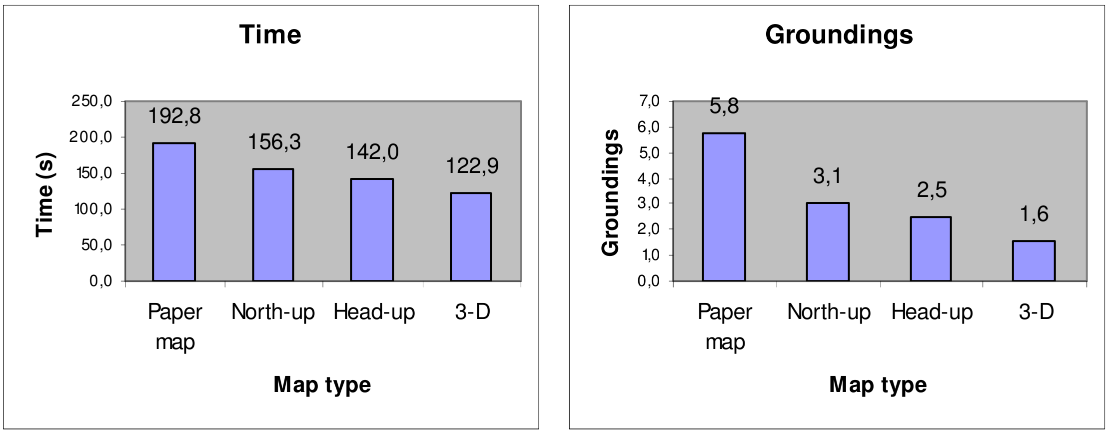

Figure 2. Left diagram shows the time (mean values for all test subjects) for the different of map types. The right one shows the number of groundings (mean values for all test subjects) for the different map types.

The difference in time on track between the map type is statistically significant at the 1% level. ($F_{(3,87,0.01)}=39,3$, $p<0,01$). The same counts for the difference in number of groundings between the different maps. ($F_{(3,87,0.01)}=20,0$, $p<0,01$). The subjects subjectively ranked the ease of use of the different map types on a scale from 1 (the easiest) to 4 (the hardest). The 3-D map was ranked the easiest with a mean index of 1,52. Second easiest was the head-up at 1,92. Ranked as number three was the north-up at 2,93 and ranked as the hardest to use was the paper map at a mean index of 3,67. Thus the subjects' ranking order followed the logged results from the experiment.

4.1 Effect of professional experience

We compare the mean results from the high-speed navigators, merchant marine officers and cadets with each other. All three subgroups have the same tendency as the group as a whole, regarding both their time on track and their groundings for the different map types. All groups had their most effective runs with the 3-D map and their least effective with the paper map while the head-up and north-up ranked second and third respectively. The only exception is the cadets who had their lowest number of groundings with the head-up map (see Figure 3&4).

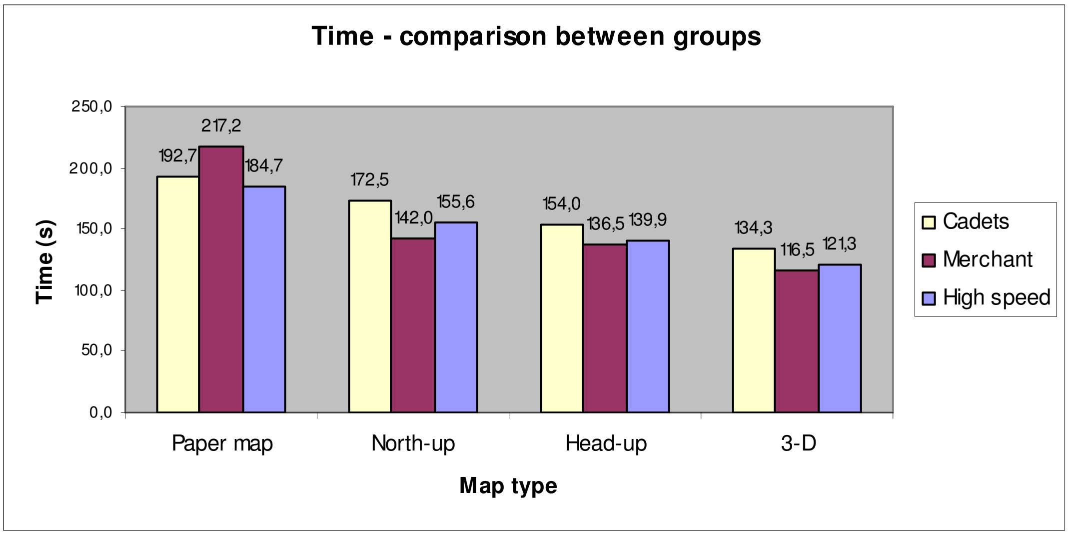

Figure 3. Time on track (mean values in seconds) – comparison between groups of different professional experience.

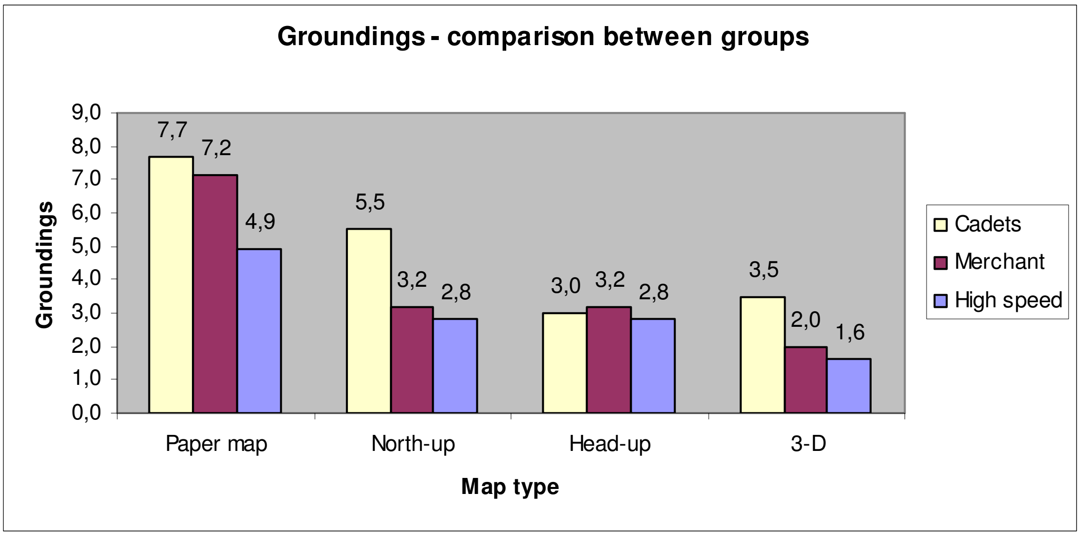

Figure 4. Number of groundings (mean values) – comparison between groups of different professional experience.

4.2 Comparison of maritime vs. non-maritime personnel

Comparing the results with Porathe's earlier they follow the same tendency - the 3-D map is ranked first with the head-up as second, the north-up as third and with the paper map as number four. The difference in times not large, in fact Porathe's group had shorter times on the 3-D map (see Table 1). Looking on the number of groundings, the test persons from the maritime domain (Prison) had less on all map types (see Table 12). The difference is about 29% between the two studies with the 3-D map diverging, differing only by 10%.

Table 1. Time on track (mean values in seconds) - comparison between Porathe & Prison.

Map type	Paper map	North up	Head up	3-D
Porathe	230,4	167,4	142,1	111,4
Prison	192,8	156,3	142	122,9

Table 2. Number of groundings (mean values) - comparison between Porathe & Prison.

Map type	Paper map	North up	Head up	3-D
Porathe	8,2	4,2	3,6	1,7
Prison	5,8	3,1	2,5	1,6

5 Discussion

The 3-D map showed to be the most efficient navigational aid through the maze, scoring the shortest time on track and the lowest number of groundings. Second was the head-up map, third the north-up map and fourth was the paper map. A possible explanation might be that the paper map is harder to use because you do not get your position presented by the system. Besides keeping track of the relative position of objects around you, you also have to keep track of your own position on the map. Using the north-up, you get your position from the system, but when driving south a turn to starboard (right) on the map is in fact a port (left) turn in reality. With the head-up you do not have this problem, resulting in that all objects and directions resembles those in your real world in front of you. With all three here mentioned types you still have to translate the exocentric picture on the map to the egocentric view we get through our eyes. This explains the higher ease of use of the 3-D map. The picture on the map resembles our own of the setting around us. It thereby removes the need for advanced translations and mental rotations of the map, compared to the real world, thus making it the easiest aid to navigation of the four.

5.1 Results between groups

When discussing the results between groups (high-speed navigators, merchant marine officers and cadets) it should be noted that the results are not statistically significant as the individual groups are too small. Still there are some observations worth noting. The different groups seem to have quite similar time on track for the respective map types while their respective number of groundings differ more. Why this is, we do not know. A possible explanation is that a short time is not the main goal but scoring low on groundings is. Another reason could be that the subjects with the better performances also have a truer picture of their position on the track. Looking at number of groundings there is a big difference for the paper map. The high-speed navigators scored over 30% better result then the group with the second lowest number of groundings. This might be explained by the fact that they mainly navigate using paper charts, in higher speeds and cognitively demanding situations and that they are using a solid navigational methodology. The merchant marine officers also use their way of navigating together with time at sea compared to the cadets who are not yet very experienced, which may explain why they had the longest time on track and the most groundings of the three groups.

5.2 Results compared to Porathe's earlier study

Porathe's test subjects scored shorter times on track when the 3-D map was used than the test subjects in the present study. Also Prison's results concerning the number of groundings gave a 29% better scoring than Porathe's for all map types except for the 3-D map. This suggest that persons from the maritime domain do better with the traditional navigational aids then people with none or little navigational experience. But when using the 3-D map the difference between the two groups is clearly reduced. This might indicate that the 3-D map are more intuitive to use as a navigational aid compared to the more traditional ones.

5.3 Future work

Observations together with statements from the test objects indicate that:
Subjects tend to get more stuck in the screen looking more on the application with the 3-D map. Why is that? When technology works you trust it, when it does not you have to look for other means of guidance resulting in a better overview of the surroundings. How would this show itself in a real life situation? What risks might emerge from using this technology and how do you deal with them?
Maritime personnel use objects in their surroundings both as steering points ahead (to aim on) and as turning points (objects at right angles from their track to help them make the turn at the right place). You tend to lose this angularity using the egocentric view of the 3-D map. How do you handle this? Further, you may lose the overview of the charted terrain with the 3-D map compared to the exocentric 2-D presentations. How is this to be solved?
All these and other questions have to be studied in more detail. Future studies should take place in a ship simulator or at sea in a more realistic setting.
The results presented here clearly point in the same direction as Porathe's earlier findings, thereby verifying the maze method as one with which one can measure navigational performance to a certain degree. The same setting could be used to study navigational performance under various influences, for example fatigue and alcohol.

6 Acknowledgements

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