Navigation performances of a blind sailor using a haptic and auditory cartographic system on board

Mathieu Simonnet
Naval Research Institute, France
Ea 3634
mathieu.simonnet@ecole-navale.fr

Stephane Vieilledent
Université Européenne de Bretagne, France
LISyC - Ea 3883
stephane.vieilledent@univ-brest.fr

Jacques Tisseau
Université Européenne de Bretagne, France
ENIB, LISyC - Ea 3883
tisseau@enib.fr

ABSTRACT
In this case study, we investigated the influence of two displays in a haptic and auditory navigation tool used on board by a blind sailor. The displays differed in their spatial frames of reference. We assessed the control and representation of his course after having used a force feed-back device as a maritime cane (i.e. egocentric) or as a mean to conventionally consult an updated geographic information system (i.e. allocentric). Results tended to show that the egocentric condition was better for precise course control and the allocentric one more efficient for building an accurate mental representation.

Keywords
Blindness, navigation, haptic, frame of reference, sailing.

1. INTRODUCTION
Nowadays it is well known that blind people can take advantage of virtual navigation. Indeed, various experiments have shown interesting results in different types of environments. Jansson and Perdersen studied a virtual map of North America States and showed that it was difficult to navigate with a mouse without visual feedback [3]. Gutierrez assessed a geographical haptic representation of Madrid (Spain) by asking twelve blind people to create and depict a route between two points. Participants completed the tasks without major difficulty and stated that the application was attractive and easy to use [2]. At the same time, Magnusson and Rassmus-Gröhn investigated the transfer between an egocentric haptic virtual environment and a real street in a district of Lund (Sweden). Here, they asked participants to prepare and realize an itinerary from a bus stop to a music hall. Results show that blind people who were good at navigating with a cane also were good at exploring with the haptic device. A transfer seemed to happen between virtual and real worlds [5]. More recently, Lahav and Mioduser compared non visual spatial representations obtained after having explored real and virtual classrooms. "The results were clearly indicative of the contribution of learning with the virtual environment to the participants' anticipatory mapping of the target space and consequently to their successful performance in the real space" [4]. Looking at these studies, no-one can deny that blind people take great advantage of exploring virtual environment to learn surroundings. However wide open spaces such as lands, mountains or oceans have not been studied thoroughly yet. Thus, little is still known about the benefits of virtual environments to help blind people to master these quite extreme navigations that challenge spatial orientation in natural places i.e. when the choice of the displacement is not constrained by any road. Focusing on blind sailors, we recently suggested that they can take advantage of virtual navigation training sessions to locate themselves in real maritime spaces. More precisely, results revealed that a subject was more accurate in real environments after virtual navigation in an egocentric frame of reference (i.e. the map moves around the ship) than in an allocentric one (i.e. the ship moves on the map) [6]. This result raises the question of the coordination of the spatial frames of reference between virtual and real navigations. Thus, the present investigation aims to test the influence of the spatial frames of reference display when a blind sailor is offered the opportunity to use a haptic and auditory navigation tool inside the ship during the real voyage. How can virtual and real information be combined? Is it more beneficial to display information in an egocentric frame of reference and to use a phantom force feedback device as a virtual cane? Or is it better to display the map in an allocentric frame of reference in order to build more stable mental invariants?

2. EXPERIMENT
The participant was thirty years old, lost vision at eighteen and has been sailing for eight years. During the task he was asked to control navigation using *SeaTouch*, a haptic and auditory navigation software interfaced with a Phantom Omni (*Sensable*). Here, we tested two conditions. In the first condition, information was provided in an egocentric frame of reference, i.e. the heading of the boat was up oriented and the blind sailor could use the phantom haptic interface as a long maritime cane. The ship was not moving in the workspace but the map shifted around the sailboat. In the second condition, cartographic information was displayed in an allocentric frame of reference, i.e. conventionally the north was up and the ship moved on a static virtual map during the real voyage. The role of the participant was entirely cartographic. He had to reach seven consecutive waypoints by indicating to the crew the different heading directions they had to follow taking into account the wind direction (Fig.1). To avoid potential learning effects and biases due to different waypoints configurations, we used the same waypoints layout that we rotated from one hundred degrees between the two conditions. After the sailing session, back to the harbor, we asked the participant to draw the waypoints layout on a tactile paper sheet. In this study, we assessed two types of data. On the one hand, we mea-

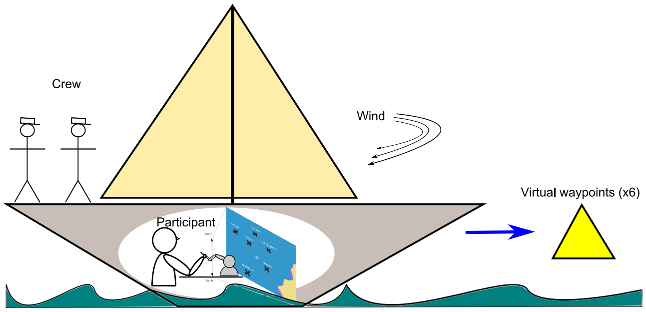

Figure 1: Experimental task. The participant was the navigator and demanded to the crew to maintain different headings to realize the course.

sured the seven euclidian distances between the waypoints and the nearest positions of the ship during the course. This provided us with an indicator of the accuracy of the navigation control. On the other hand, we compared the layouts of waypoints drawn on the tactile paper and their real positions. To be able to compare these two configurations, we considered that the first waypoint was drawn at its right position. Then, the distances were managed by applying the scale used in the phantom workspace during navigation (1:1000).

3. RESULTS

The main result showed that the participant passed 16 ($\pm$14) meters away from the waypoints in the egocentric condition *versus* 44 ($\pm$44) meters in the allocentric conditions. In other words, he controlled the course three times more accurately in the first condition than in the second one. Another interesting and surprising result was given when the participant was asked to draw the waypoints layout. Indeed, after navigating with the egocentric display, he was just unable to perform the required task and to draw the waypoints layout. He only could say that the fourth waypoint was west to the fifth one which was actually south west. Conversely, after navigating with the allocentric display, the participant was able to draw a configuration on the tactile paper sheet and the drawn waypoints were 127 ($\pm$67) meters away from the actual waypoints. Applying bidimensional regression techniques [1], we found that the correlation coefficient r was equal to 0.86 indicating that the mental representation and the actual one were quite similar whereas there was no similarity at all in the egocentric condition since the participant remained unable to draw any configuration layout. In brief, the representation built in the allocentric condition was much more accurate than the one built in the egocentric one.

4. DISCUSSION

These results suggest that the haptic egocentric display is more efficient for controlling a maritime itinerary whereas allocentric navigation seems to better fit to the building of a mental map of maritime environment without vision. Indeed, the use of the haptic force-feedback device inside the ship during voyage made haptically perceptible that which was not perceptible without vision. Even if the global pictures of the ship trajectories and the haptic patterns of exploration did not clearly look different (Fig.2), verbal report

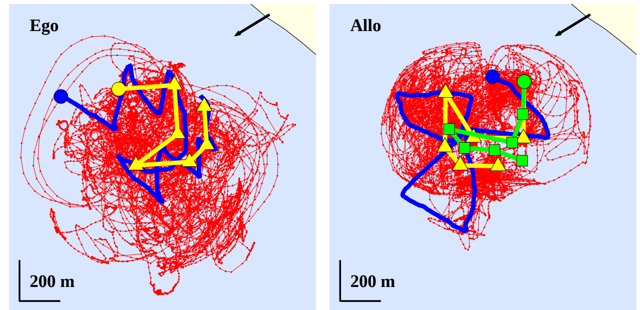

Figure 2: Visualization of tracks (yellow triangles for waypoints), courses (large blue lines), exploration patterns (thin red lines) during voyages and mental representation of the waypoints layout (green squares) after navigation. Circles represent the departure points of tracks and courses. Black arrows indicate the wind direction. The picture on the left shows the results in the egocentric condition and on the right in the allocentric one. No mental representation of the waypoints appears on the left picture because the participant was not able to draw it in this condition.

provided by the participant revealed that in the egocentric condition, it was easy to feel the difference between the ship heading (i.e. bottom-up axis of the Phantom workspace) and the direction of the current waypoint. Conversely, in the allocentric condition, the participant had to follow the ship to perceive a raw heading direction and then had to perform a mental rotation to deduce necessary adjustments in order to reach the next waypoint. This second condition appeared less intuitive to the participant who explained that he permanently referred to the ship in the egocentric condition because the map was keeping moving, while he mostly consulted the stable map in the allocentric condition.

5. REFERENCES

[1] A. Friedman and B. Kohler. Bidimensional regression: Assessing the configural similarity and accuracy of cognitive maps and other two-dimensional data sets. *Psychological Methods*, 8:468–491, 2003.

[2] T. Gutierrez. Enhanced network accessibility for the blind and visually impaired. Technical report, Labein, Madrid., 2004.

[3] G. Jansson and P. Pedersen. Obtaining geographical information from a virtual map with a haptic mouse. In *Proceedings of XXII International Cartographic Conference (ICC2005)*, 9-16 July, A Coruna, 2005, Spain.

[4] O. Lahav and D. Mioduser. Haptic-feedback support for cognitive mapping of unknow spaces by people who are blind. *International Journal of Human-Computer Studies*, 66:23–35, 2008.

[5] C. Magnusson and K. Rassmus-Gröhn. A Dynamic Haptic-Audio Traffic Environment. *Proc. of Eurohaptics*, pages 5–7, 2004.

[6] M. Simonnet, S. Vieilledent, S. Jacobson, and Tisseau. The assessment of non visual maritime cognitive maps of a blind sailor. *Journal of maps*, (In press).