User-Centered Map Design

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Abstract

Many people find map reading difficult. The problem lies in translating an exocentric bird's-eye perspective of traditional maps into an egocentric perspective of the human vision. The experiment presented here suggests that electronic egocentric map displays using real-time 3-D and GPS positioning technology are more efficient, less erroneous, and more user-friendly than traditional static maps or electronic north-up or head-up maps.

Keywords

Map design, wayfinding, mental rotations, nautical charts, user-centered design

Citation

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Introduction

Many people find map reading difficult. We all have a notion of how maps are designed to help us find our way, but even the most skilled among us have, at some time, have had problems with wayfinding. Humans have devised all kinds of maps over the centuries, so why is it still so difficult to use maps today?

Most maps are a pictorial representations of the physical world depicted from a synthetic bird's-eye perspective. We call this perspective *exocentric*, because it is an exterior view or things. We have to go outside of ourselves to understand the landscape this way; we become outside observers observing ourselves as an object traveling over the surface of the map. This is a very different perspective from the limited view of our eyes as we walk about in our everyday *egocentric* (or internal) perspective. It is, however, only natural that the exocentric approach has been chosen for maps, because the overview is what we often need in narrow streets or deep forest. Without a map we would seek a hilltop or an open space to get a glimpse of the surroundings. There is, however, a difficulty with this exocentric view.

The difficulty arises in the discrepancy between the exocentric and egocentric perspectives. Since the days of Ptolemy, maps normally have a north-up reading orientation. The result is that a southbound traveler who on the map sees the next street go off to the right, in reality has to turn left. To compare the map with the physical world the traveler has to mentally rotate the map to fit to the world (or often physically too, turning it so that the forward direction is oriented up on the map – called "head-up" orientation). These mental rotations are difficult and time consuming as Shepard & Metzler showed in 1971. This so called *spatial ability* of mentally rotating a map can indeed be trained, but different people have varying capabilities, and although the individual differences are larger than the general ones, men are more facile than women, and the young more facile than the elderly. Research in this field has been collected by Halpen (2000). Additionally, much has been much written about human wayfinding capability; Tversky (1993), Golledge (1999) and Wickens & Hollands (2000) are excellent examples of writing on this subject.

Modern technology affords new ways of visualizing maps and supporting wayfinding. For example, car navigation systems based on GPS positioning have very successfully used an almost egocentric perspective by slanting the map and using verbal wayfinding instructions based on the egocentric perspective to guide drivers. At sea, electronic nautical chart systems and radar displays use both north-up and head-up orientations and show the own ship's position in the chart. So, what is then the most efficient display perspective for route guidance?

An information design research project on 3-D nautical charts at Mälardalen University in Sweden conducted a laboratory experiment to test different map displays and perspectives. The aim was to find out which display types were more efficient than others.

Method

Purpose

The hypothesis for the experiment was that navigating in a dynamic egocentric frame of reference is more efficient (faster due to quicker decision making and less erroneous) than in a static exocentric frame of reference. The experiment tested this hypothesis using four kinds of maps.

The experiment space

A 6 meter by 6 meter square was marked out on the floor of a large room. This was the "confined waters" of the experiment. Through this supposedly "shallow" water area, a winding "deep-water" channel was designed using an invisible grid of 10 by 10 squares. A chair, some boxes and a paper tube acted as visible navigational aids. Four different channel patterns were designed, one of them can be seen in Figure 1 (the only visible difference between the four patterns would be the different positions of the navigational aids, the pattern of the channels was only visible on the maps).

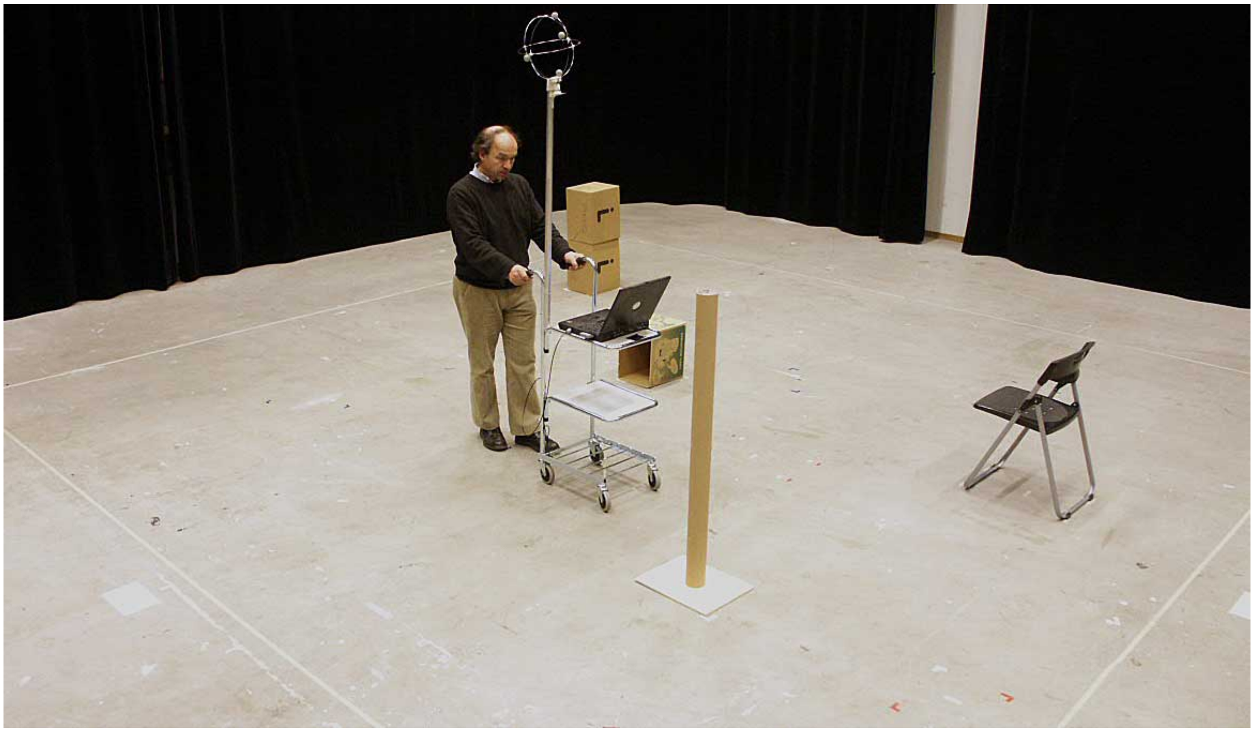
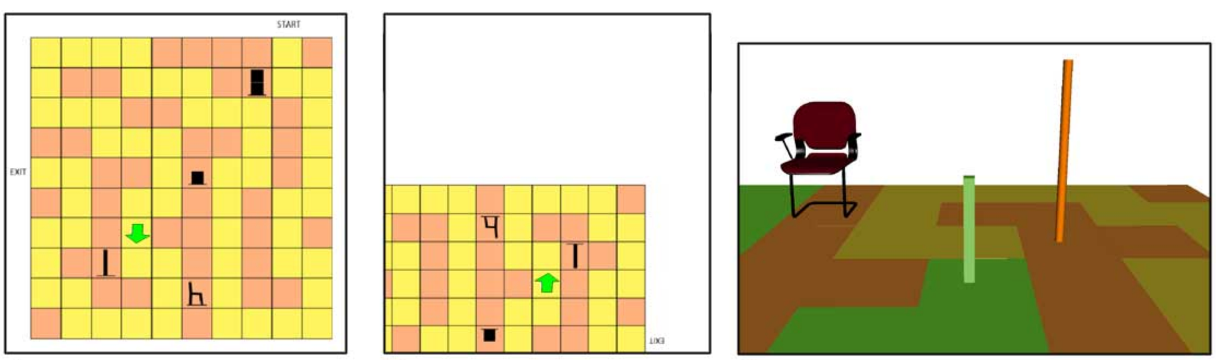


Figure 1. One of the four experimental spaces: a 6m by 6m area with four navigational aids and the author driving the cart. The map types A, B, and C displayed on the laptop screen at this very instant can be seen in Figure 2. Photo Emilie Porathe.

The tested map types

The maps for the experiment were based on a grid of 10 squares across and 10 squares down (see Figure 2). Through the shallow water area (red squares), the deep water channel winded (yellow squares). In all four map designs, the length and the number of turns of the channel was about the same. The navigational aids were depicted on the maps as well. For each of the four map designs one 2-D map and one 3-D model were constructed.



A B C

Figure 2. A. the 2-D map in the north-up mode as it was shown on the screen of the laptop computer on the cart for the very position shown in the top picture. The middle (B) map is the 2-D map in course-up mode and right (C) is the 3-D map.

Four different display perspectives were tested in the experiment:

A. **The north-up map**. A static exocentric 2-D map was displayed on the screen of the laptop computer, which was fitted on the cart. The map was oriented with north up, but during the experiment, the “north” direction in the room was changed for each of the four channel designs. The location and heading of the cart was visualized on the screen by a moving green arrow.

B. **The head-up map**. A dynamic exocentric 2-D map could translate and rotate on the screen. The position of the cart was depicted by a static green arrow in the lower center of the screen.

C. **The 3-D map**. A dynamic 3-D model of the experiment space could translate and rotate in the x-y plane. A static green pole marked the position of the cart. The virtual camera showing the egocentric view supposedly hung on top of and behind the subject who was pushing the cart.

D. **The paper map.** A print-out of the exocentric 2-D map. This map is not shown in Figure 2, but was identical with map A minus the green arrow. The subjects held the paper map in one hand while pushing the cart with the other.

The vehicle

The cart used in the experiment covered a ground plane of 0.45m by 0.38m. All four of its wheels could rotate, making the cart easy to maneuver. The cart had a shelf on which a laptop computer was placed. The computer ran on batteries so no cords were attached to the cart during the experiment. The computer was fitted with a custom-made, real-time, 3-D software application that was used to show the 3-D egocentric maps, the 2-D exocentric north-up, and head-up maps. This application also monitored the movement of the cart and logged the time it took for the subject to pass through the channel and the number of “groundings” made by the subjects (the cart entering into the red squares).

The coordinates of the cart (x, y, and heading) was sent from a tracking system by wireless LAN and received by the laptop to mimic a GPS system. The uncertainty of the system setup was less than 0.02m. The update frequency of the tracking system was 50 Hz.

Test subjects

Forty-five subjects were volunteers from a population of available students, teachers, and personnel at Mälardalen University; 24 male and 21 female, ages 16 to 63.

Experimental set-up

Each subject drove the cart four times through the four different channel designs. The order of these designs was always the same. For each time, they used a different display type. The order of the display types was random, so one subject might start out with the egocentric 3-D display on track 1 and the next subject might start out with the paper map.

The test subjects were instructed that the purpose was to drive the cart though the channel (the yellow track) as fast as possible without groundings (entering into the red areas on the map). It was explained to the subjects that this was not a competition; the experiment was to test the efficiency of different maps, not the skills of the participants. They should pick a strategy (from quick and sloppy to slow and careful) that they felt comfortable with and try to stick to that same strategy throughout the experiment. Then, they were guided through a practice session. When the subject felt ready, the experiment started.

After the sessions, a short interview took place. The subjects were asked about their previous navigation experience and they were asked to fill in a ranking form where they ranked the four map types based on ease of use.

Results

As shown on the right in Figure 3, the result showed that the 3-D chart was “fastest” with a mean time through the channels (tracks) for all 45 participants of 111 seconds, the head-up chart came second with a mean of 142 seconds, then north-up map with 167 and the paper chart with 230 seconds. In this test, decision making using a head-up map was 28% slower than using a 3-D map, and using a north-up map 50% slower. Decision-making using a traditional paper map was over 100% slower than using the 3-D map.

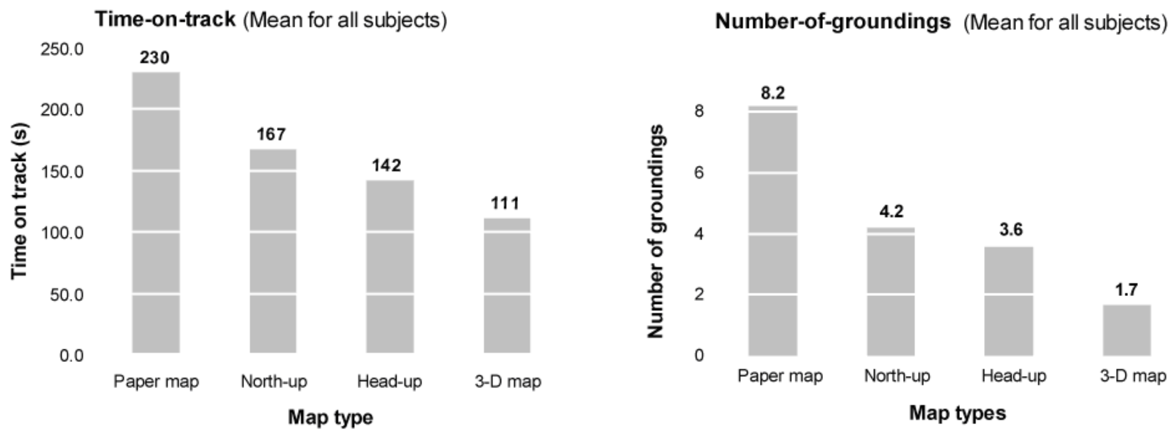


Figure 3. The left diagram shows the mean time for all subjects on the track according to the four different map types. The right diagram shows the mean number of "groundings" made by the subjects for the four different map types.

Looking at mean for the number of "groundings" gave the same results. Use of the 3-D map resulted in the least number of groundings, with a mean of 1.7 groundings for the whole group; the mean number of errors using the head-up map was 3.6, for north-up was 4.2, and for the paper map was 8.2. Wayfinding using a head-up map resulted in more than twice as many groundings as navigation using the 3-D map, and using a north-up map resulted in 1.5 times more groundings. Using the paper map resulted in almost five times as many groundings as using the 3-D map. The means of all subjects' time on track and number of groundings according to map type are shown to the right in Figure 3.

The difference in time on track between the map types was statistically significant at the 1% level. ($F_{(3,132,0.01)} = 46.6$, $p < 0.01$). The same was true for the number of "groundings". The influence of the map type on the number of groundings is statistically significant at the 1% level ($F_{(3,129,0.01)} = 3.94$, $p < 0.01$).

The subjects were also asked to rank the ease of use of the different map types from 1 through 4, where "1" was the easiest and "4" the most difficult map to use. The 3-D map was classified as the easiest, with a mean index of 1.13, followed by the head-up map with a mean index of 2.29; north-up had a 3.24 index, and the paper map was 3.33. The paper and the north-up maps were considered almost equally difficult to use (see Figure 4).

For a more thorough presentation of this experiment and how age, gender, navigational experience and spatial ability influenced the results, see Porathe (2006).

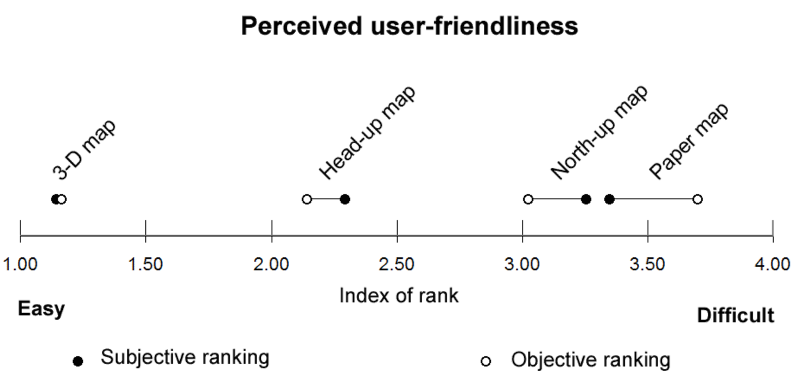


Figure 4. After the experiment, the subjects were asked to rank the user-friendliness of the four map types: the egocentric 3-D map was ranked as the easiest to use and the traditional paper map as the hardest (black spots). As a comparison, the objective mean result is also added (white spots).

Discussion

The result of this experiment suggested that for route guidance, maps displayed in an egocentric perspective are more efficient (faster decision making), less erroneous, and more user-friendly than maps displayed in the traditional exocentric perspective. The map display types were not tested for route planning or judging distance. In these situations, it is probable that the exocentric perspective is preferable.

The research is aimed at developing a new kind of 3-D nautical charts. So far, the results have been positive and future tests with navy personal and field trials will show if the results hold. Figure 5 shows a screenshot from a prototype application containing both the traditional, exocentric electronic charts and the new egocentric view.

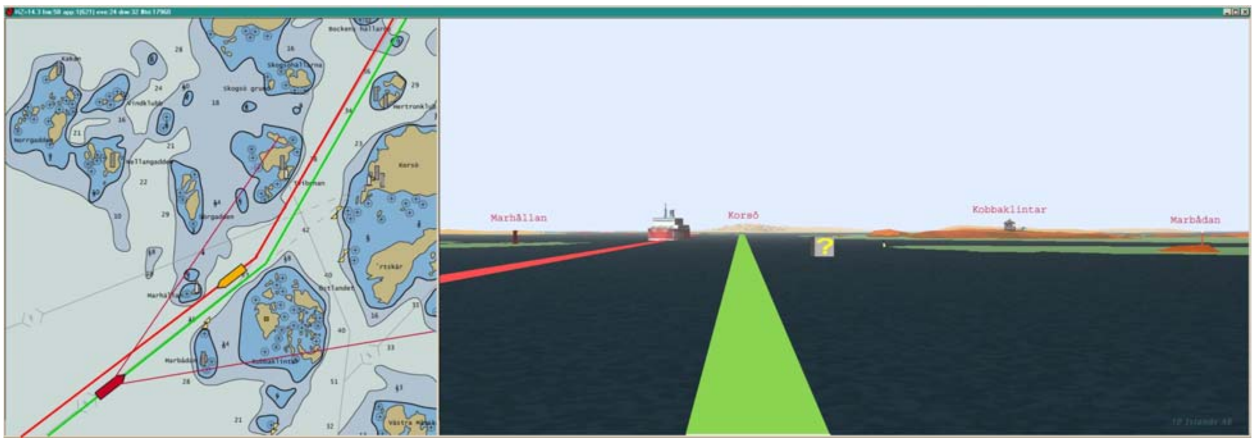


Figure 5. The Egocentric Map View implemented in a nautical chart. A screenshot showing a prototype from the research project is presented here. To the left, a traditional exocentric north-up nautical chart where the red boat is their own ship, to the right the egocentric view from their own ship's bridge. The entrance to Mariehamn in the Aland archipelago in the Baltic Sea.

Awareness of perspective and the implications of mental rotations is needed when making maps and assembly instructions. The awareness can also affect the design and placement of controls in environments, such as a ship's bridge. The guidelines of the American Bureau of Shipping say "the consoles, including a chart table if provided, should be positioned so that the instruments they contain are mounted facing a person who is looking forward" (American Bureau of Shipping, 2003). Older ships do not always comply with this rule (see Figure 6).

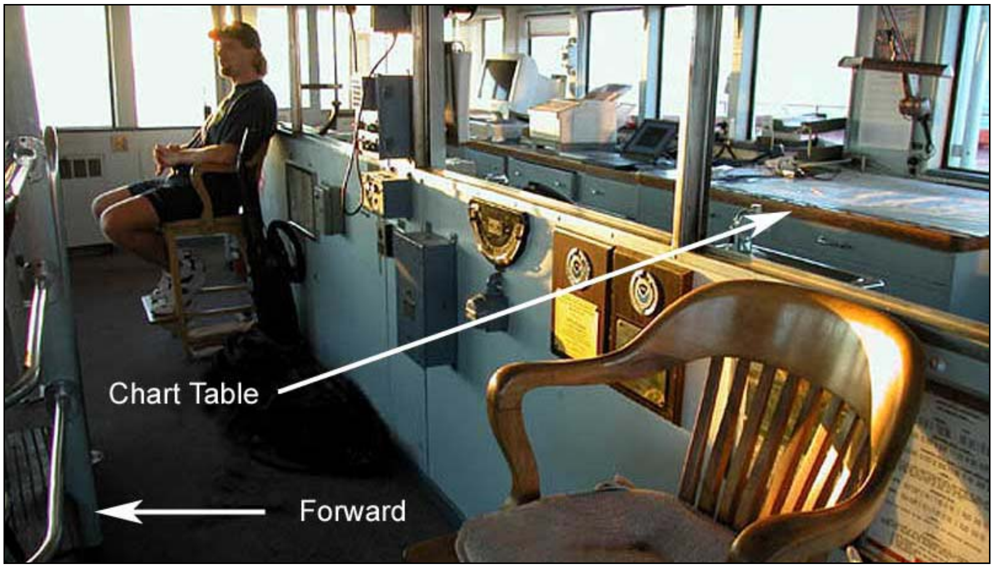


Figure 6. Chart reading backwards is bad usability. The wheelhouse of MS Wilfred Sykes. The navigator reading the charts is facing aft. Photo: Roger LeLievre, http://www.boatnerd.com/pictures/fleet/sykesb.htm, [2006, February].

The same principles are useful when making you-are-here maps (see Figure 7) and, more importantly, when making emergency exit maps. How should the map on the inside of the hotel room door look? If your evacuation route is to the left outside the door, but the map is oriented so that your room is shown on the top side of the corridor with the door facing down, the evacuation route arrow will point to the right on the map; you will need to think twice about which way to run.

Figure 7. For you-are-here maps the recommendation is that when facing the map the area in front of you (that is, behind the map) should be at the top of the map (e.g., Wickens & Hollands, 2000). In this example from Gripsholm castle in Sweden, the map should have been turned 45 degrees counter clockwise. Luckily, the map stand was not placed on the other side of the road. Photo by the author.

Assembly instructions are another example where constancy of perspective and mental rotations plays an important role for user-friendliness (see Figure 8).

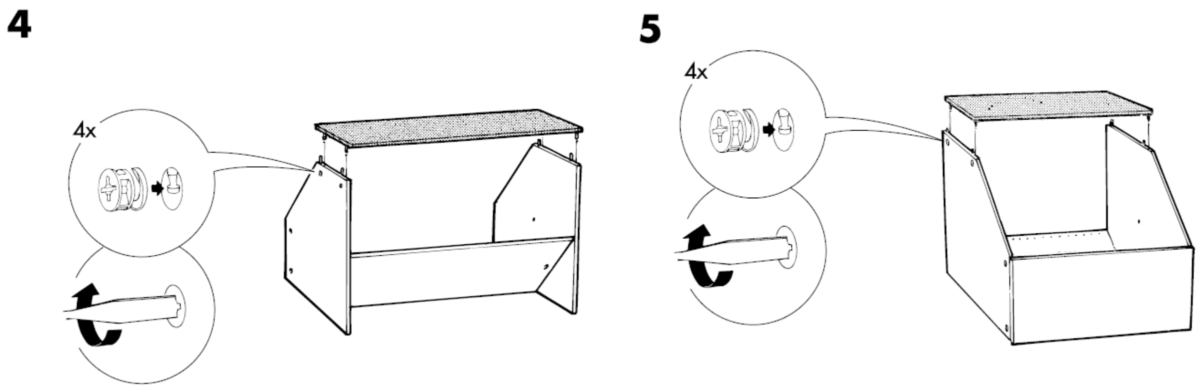


figure 7. An ambiguous example from an IKEA assembly instruction. Didn't I just put these four screws in?

Conclusion

The experiment presented above strongly suggest that the egocentric map perspective is more efficient in route-guiding situations than traditional exocentric maps. such as paper maps and electronic maps in north-up and head-up orientation. The next step will be to redo the laboratory experiment with experienced navy combat boat drivers and to do sea trials to test the ecological validity.

The result should be directly relevant in wayfinding applications for land, sea, and air vehicles and handheld devices for pedestrian route guidance. But also in several other areas of visual design where abstractions like maps, drawings, or blue prints are handled and compared with real world objects or scenes, for example, assembly and maintenance instructions, emergency evacuations plans, and so on.

In some cases, a human-centered design perspective might mean just that: a human-centered perspective.

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