Do humans know the imprecision inherent in a map?

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Reading maps and using them to find the way from one location to another is part of our culture. When creating maps, reality is abstracted and scaled down. This process diminishes the precision with which locations are represented. Special symbols can only partly compensate this effect. A neglected question is whether humans take the imprecision of a map into account when searching for a location. We first clarify the difference between accuracy, reliability and precision. Thereafter we present an experiment investigating whether humans adapt their behaviour when searching for a location that was more or less precisely defined on a map.

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1. Precision, reliability and accuracy of a map

Reading a map is something we take for granted that all can do it. However, we differ in how we read maps and how we represent the information on a map. That is on the one hand due to sex and individual differences in spatial ability (see for example Herlitz et al., 1999; Ishikawa & Montello, 2006; Postma et al., 2004). On the other hand maps do differ in the accuracy, precision and reliability with which they display the reality. The purpose of a map determines how accurate, precise and reliable the map is. First, what exactly are accuracy, precision and reliability? Second, do humans pay attention to this?

When using maps to navigate from the current location to a target location, we have to take the precision of the map into account. A map is a scaled version of nature and this transformation influences the precision of a map. A road atlas contains enough information for navigating along roads but is imprecise, i.e. has too little information to find a cache/control or hike along paths. Still a hiking map and a highway map can be accurate. They would not be accurate if there is a difference between the average measurement and the true value, in other words if the coordinates of a place on the map deviates from the actual coordinates. That is not a trivial issue. Maps that are based on the magnetic earth field will change their coordinates. See for example the recent decision to rename runways (http://www.physorg.com/news/2011-01-tampa-airport-runways-renumbered-due.html).

In addition, maps can differ in their reliability. Reliability indicates how well a place is correctly identifiable or in the example of a cache how likely a cache is to be in the place indicated on the map. The reliability and precision with which a place is indicated do interact in a non-linear way (Pfuhl et al., 2010). For example a reliable but not precisely represented cache can be easier to find than a precisely defined but unreliable cache. Figure 1 shows the three terms on the example of caching.

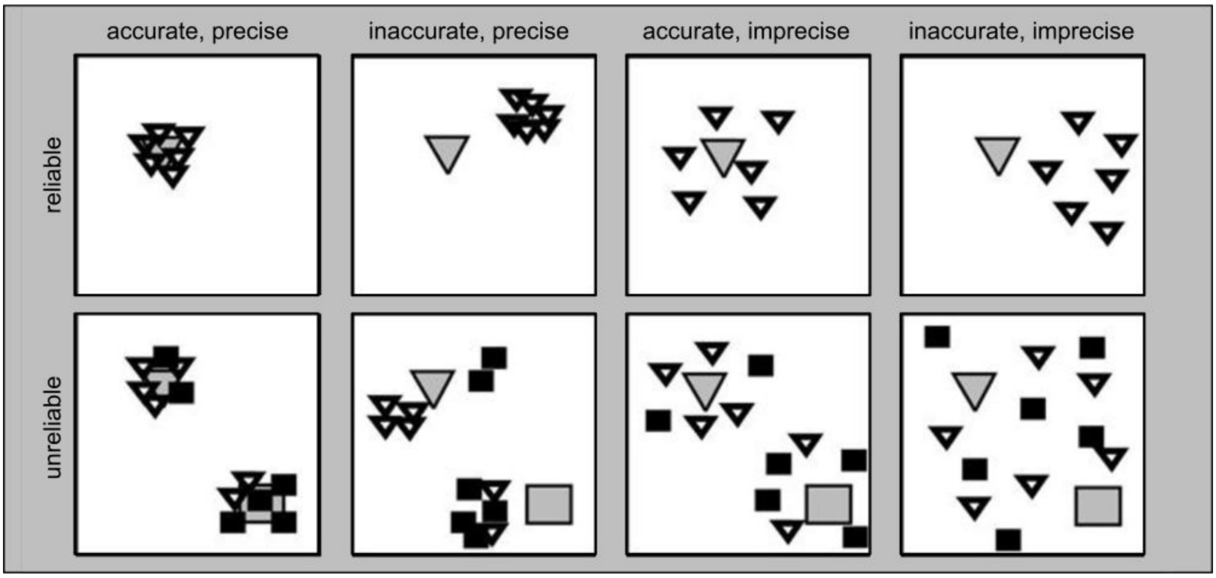

Figure 1: Interaction of precision, reliability and accuracy of a map

Let us first look at the case where the map is reliable, shown in the first row. We can have four cases:

- Leftmost) the measurement of the cache location is reliable, accurate and precise. Many places on cartographic maps fall into this category.
- Inner left) the measurements are reliable and precise but there is an inherent bias making the location inaccurate.
- Inner right) the cache location is reliable, accurate but imprecise. Due to scaling many places are not precisely given on maps.
- Rightmost) The location is measured reliably but is imprecisely and has an inherent bias. Many touristic maps represent places in such a sloopy way, i.e. the maps are not helpful in navigating.
- In the bottom row the map is unreliable. Here we have in addition the possibility to mix up to different locations. Often the mixing up is due to misnaming places. An interesting case is the location of the North Pole. There is a geographic and a magnetic North Pole. Due to the wandering of the magnetic field navigating to the North Pole by compass is an unreliable, inaccurate and imprecise task compared to navigating to the geographic North Pole by satellite position systems.

Reliability is rarely manipulated in cartography. Accuracy is the hallmark of a good map. However, precision is a factor one has to take into account. Many maps increase precision by using special symbols for prominent features on a map. This can add in resetting the accumulated errors in navigation (Biegler, 2000). But it also defines a place by a feature and its location. For example a church in a village receives a special symbol and can hence found easier than a bakery which is just marked as any other house on a cartographic map. For fine-orientating tasks special maps with their symbols are used. Nevertheless those maps still cannot precisely define all locations.

2. Experiment

To see how well humans take the imperfection of maps into account we designed a task where we used an accurate and reliable map. The choice was a map used for the sport orienteering. On such a map there are locations that were clearly defined, like crossings but also locations that back-transformed amounted to a 20 m by 20 m area of where a control location could be. We recruited 11 orienteering runners. In this sport one uses maps with scales from 1:3000 to 1:20,000, and they contain special symbols indicating for examples roots, wells, hollows, hayboxes. These features can serve as controls that have to be found and by providing a punching device can be checked. In an orienteering competition 10-40 controls have to be punched, and the fastest who found all controls wins. The controls are marked on a map which the runner receives at the start. A compass is allowed but no other aid. In a real competition all controls are where they have been drawn on the map (for more information please visit http://www.orienteering.org). During training, however, it is common not to hang all controls / punching devices. We exploited this fact by telling the subjects that they shall treat this as a competition but a few controls will be missing. The subjects were not told how many controls were missing or where or when to expect them. The explanation given was that we wanted to see how they responded to missing controls. The course had 14 controls on the map but only 10 where equipped with a punching device. The four missing controls differed in how precisely they were defined on the map. For example one control was a root (precise), and one a swamp area (imprecise).

Subjects had to carry a handheld Global Positioning System (GPS) receiver but not use it for orientation. The GPS (Garmin) encoded the position every 2 seconds. The course took on average 1h to run. Subjects were told that the first control is definitely there so that they can get used to how difficult the hiding of the controls will be. Subjects received a payoff depending on how many hits and misses they had. I.e. not finding an existing control resulted in negative points (subtracting money).

From the GPS the time spent in the particular area near the control was calculated. For comparison the analysed area around a control was similar in size for all controls. The velocity near or at the control location was expressed as travel distance per seconds and was used as the dependent variable. The prediction was that the fewer details the map contained for a control location the more time subjects spent within the area around the control searching for it. After the subjects finished the course, the control sheets were checked and the GPS handed back. The majority of subjects were asked which controls they found difficult, and if they did not find them how they based the decision on leaving / running to the next control. The terrain of the controls was carefully selected so that running speed per se was not different (data not shown).

3. Results

The majority of the 11 subjects found all existing controls. Controls 4, 6, 10 and 12 did not exist. Three subjects did not find the existing control 5, one missed control 3, and two missed the last control. 7 subjects gave valuable classification of control difficulty. Control 10 was described as difficult by all subjects, controls 4 and 12 as easy. Control 6 was more difficult than controls 4 and 12, but not as though as control 10 for three of the subjects. Based on this, the intended manipulation worked and controls 4 and 12 were “easy” and controls 6 and 10 “difficult” with respect to judging whether the control was gone or just well hidden. For 8 out of 11 subjects the GPS coverage was sufficient to allow data analysis.

At a control that existed and required punching, subjects' average velocity in the area around the control was 146.5 m / s. At the easy non-existing control (number 12) subjects average velocity was higher, namely 173.58 m / s. The two as difficult categorized controls, both non-existing, had a lower velocity of 105.978 and 114.02 m /s. This difference was significant: $F(4.28) = 10.16$, $p = 0.02$.

4. Discussion

The experiment showed the humans are adapting their search based on how precisely the environment indicated a target. Experienced map readers spent not much time to decide that the control is not at the location when the location is precisely defined on the map. They continued on the track to the next control. Subjects did spent nearly 70% more time when the location was imprecisely defined on a map. This time was even more than when subjects had to register at an existing location through punching it. Thus deciding that a control was not there was costing more time at imprecise locations. But missing an existing location was also costly. The decision when to give up searching depended on the precision. That is as predicted from a mathematical model (Pfuhl et al., 2009). The model also predicts that if a control is marked on too large an area, so that there is a great imprecision one should not even start to search. However we carefully avoided this by using a fairly precise map in terms of the scaling, carefully selected the control locations, and recruited experienced map readers. Our control location selection was either easy identifiable spots like on top of tree roots (marked with a green x on orienteering maps) or on less defined spots like a spur or "nose" (contour projection rising from the surrounding ground, brown on orienteering maps). In competitions additional information is given. Locations that cover in nature an area larger than 2m by 2m have directional information like north end of a swamp spot. A next step would be to manipulate this information, i.e. making it unreliable, to see how it affects the performance. In addition one can test naïve subjects with respect to the sport orienteering. However, we had to use expert map readers because humans do orientate mostly on egocentric information and that is not given on a map (see for example Wang & Spelke, 2002).

This was an external manipulation of the precision of the target location. It is possible that subjects are basing the decision to search a bit longer in less clearly defined areas based on the previous experience that "I needed more time to find controls in similar areas" rather than on the fact that the control could be at various locations within the described area because it lacked a clear mark like a root or tree trunk. It is difficult to rule out associations or life experience of this kind when the precision is manipulated externally.

5. Conclusion

Here, we looked at whether humans familiar with map reading know that a map contains some uncertainty in describing reality. Experienced map readers do take the imprecision of a map into account. That has been shown in the actual behaviour of reduced running speed, as well as in the verbal description they gave when asked which controls they found difficult. Less experienced map readers do not recognize the imprecision of a map due to overall difficulty in interpreting maps (unpublished data). As a follow up one can look at how additional information like language can minimise the imprecision, but language itself comes with uncertainty in the meaning (Frank, 1996; Freksa, 1992).

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