Mobile Cognition: Balancing User Support and Learning

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MobileHCI '15 Adjunct, August 25-28, 2015, Copenhagen, Denmark
ACM 978-1-4503-3653-6/15/08.
http://dx.doi.org/10.1145/2786567.2794321

Abstract

People engage in mobile decision-making on a daily basis. Spatially aware mobile devices have the potential to support users in spatio-temporal decision situations by augmenting their cognitive abilities or compensating for their deficiencies. In many cases though, this technology has a negative impact on people's spatial learning of the environment, such as during wayfinding. In this position paper we argue that mobile cognition must strive for solutions that find the right balance between immediate goals and longer-term objectives such as spatial learning.

Author Keywords

Mobile cognition; mobile decision-making; spatially aware mobile devices; mobile eye tracking

ACM Classification Keywords

H.5 INFORMATION INTERFACES AND PRESENTATION

Mobile Decision-Making

Today, a large part of the world's population lives in a mobile information society and has to make a variety of decisions while on the move. Often we utilize mobile services to support us in our decision-making. Several differences exist between mobile location-based decision-making and other types of decision-making [1]. The former involves a multitude of spatio-temporal constraints that relate not only to people's spatio-temporal behavior in large-scale space [2] but also to their interaction with mobile devices, and perceptual, cognitive, and social processes. Mobile decision-making requires fast access to spatial memory and the ability to make quick decisions on the spot. Users also have to cope with technological limitations regarding their mobile devices such as small screen size, and there is the general challenge of presenting information to someone on the move. In order to investigate whether principles of generic decision-making can be transferred to mobile decision-making and find potential differences, researchers have developed tools to study the interaction between individuals, environments, and mobile devices [3].

Augmenting Human Cognition And Memory

In our GeoGazeLab (http://www.geogaze.org/) we have utilized mobile eye tracking technology [4] to trace human visual attention and use the resulting data to support people's cognitive processes and memory in a variety of applications, such as mobile guides and wayfinding services.

Mobile eye tracking

Mobile eye trackers (Figure 1) allow for measuring a person's visual attention on a stimulus in the wild instead of in the lab. The basic recordings are called gazes and we generally assume that perception takes place only if gaze remains almost still for a minimum amount of time. Gazes are therefore often aggregated spatio-temporally to fixations. A transition between two fixations is called a saccade, which is caused by a rapid movement of the eye. Eye tracking data can be used for investigating cognitive processes, such as self-localization during wayfinding [5], for activity recognition [6, 7], and as input for gaze-based assistants.

Figure 1. Mobile eye tracker (Ergoneers Dikablis Cable system) in action.

GeoGazemarks

Many eye trackers allow for real-time data access, which is the principle behind gaze-assistive systems. The GeoGazemarks concept was implemented to assist people's orientation on small-display maps [8] by augmenting their spatial memory. This is often difficult because of the restricted visible spatial context. GeoGazemarks provide the user with an aggregation of her or his gaze history on different zoom levels in order to facilitate orientation (Figure 2). Visual attention on the map is thereby recorded with eye tracking, then spatially clustered, and visualized when the user zooms out. An experimental evaluation demonstrated a significant increase in efficiency and an increase in effectiveness for a map search task compared to standard panning and zooming.

Figure 2. Gaze visualizations in GeoGazemarks: The red icons on the left represent map usage history visualization on the highest zoom level. The yellow icons on the right are clusters based on the red icons on the left. When the user zooms out, she or he is able to see the complete map usage history in the form of clusters (© Image: Ioannis Giannopoulos).

Wayfinding assistance

During wayfinding people utilize their spatial and cognitive abilities, environmental information, verbal or pictorial instructions, and often mobile devices in order to make decisions [9]. We have applied the combined recording and analysis of gaze and user position in a real-world study on mobile map usage during self-localization and wayfinding [5, 10]. Such location-aware mobile eye-tracking allows us to not only analyze *what* an individual is gazing at, but also from *where* she or he is gazing. The eye tracking data were used for measuring people's orientation strategies—e.g., gaze sequence charts for cardinal directions document whether one's orientation strategy was efficient and successful—, for measuring landmark identification, and for finding out how often and where participants use the map (Figure 3). Such data can in turn be used as input for gaze-based assistive systems. These systems could detect that a user's visual information collection strategy during self-localization is ineffective and then provide information on the correct matching between landmarks on the map and in the real world. A gaze-based assistant could also detect from characteristic gaze patterns that the user is trying to orient her- or himself, concluding that she or he is disoriented and needs help.

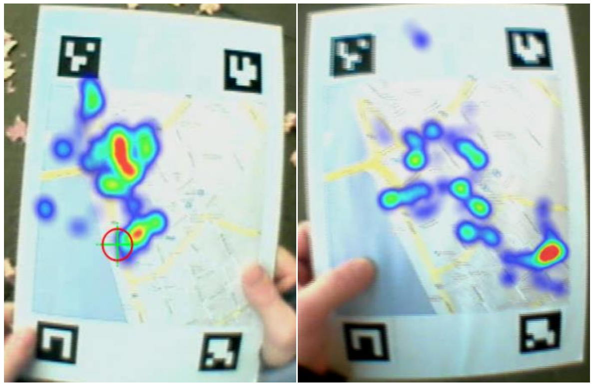

Figure 3. Attention maps for two participants trying to locate themselves on a map (© Map background: Google).

Spatial Learning

People acquire spatial knowledge from their perceptual-motor experience in the world [11]. During wayfinding we learn about the locations of landmarks, path network structures that connect places, and spatial relationships among places, even those we have not directly traveled between. Such knowledge is useful because it facilitates orientation and wayfinding in familiar environments.

Several studies have investigated the effects of navigation services and mobile devices on task performance and spatial learning in navigation. For example, spatial knowledge acquisition by participants using location based services (LBS) can be tested for landmark, route, or survey (metric) knowledge [12]. Methods include sorting images of intersections in their order of appearance along a route, pointing tasks, or drawing sketch maps. Many studies (e.g., [13, 14]) indicate that too much help from the navigation service leads to people turning off their brains. They do not process the perceived and presented information sufficiently enough in order to acquire the different kinds of spatial knowledge. A common phenomenon in automation is that attention to the environment is lacking and people's foci lie only on newly presented instructions, decoupling the actions to be performed from their spatial embedding. In addition, differences in mobile device and presentation design may have a large impact on task performance and spatial learning [15].

Best Of Both Worlds: User Support And Learning

Utilizing mobile cognition to support human cognitive processes and memory has many benefits, as shown in the examples above. But it can also lead to an 'overcompensation' of cognitive limitations, resulting in people turning off their brain and, for example, in the domain of wayfinding and navigation in decreased spatial knowledge acquisition and spatial learning. Such limited or even non-existent spatial knowledge may create problems for people when they excessively depend on mobile decision support technology and for whatever reason that technology fails. We therefore argue that it will be important to find the right balance between immediate goals, such as finding one's way from A to B, and longer-term objectives such as spatial learning of the environment.

In a previous study that compared interaction differences in the navigation services offered by Apple's iPhone and Google's Android smart-phones we demonstrated that the goals of navigation performance and learning may in fact be trade-offs [15]. More user involvement with the system and the environment, such as having to manually zoom into a digital map at decision points and comparing the map section with the real world, may lead to more wayfinding errors but also to an increased spatial learning of the environment.

Achieving user support and learning at the same time may therefore be steered through the level of user involvement. Systems should offer functionality where the user is not involved, such as satellite-based positioning, but also functionality where the user is required to perform some actions so as to foster learning and decrease technological dependency. An example for such action is the necessity to match structural landmarks, e.g., street intersections, from a map to the corresponding environment. In an ideal case user involvement is personalized to their specific capabilities and needs. For example, if a pedestrian navigation service recognizes that a user does not pay attention to her or his surroundings, it could involve her or him at the next decision point by requiring a manual zoom-in in order to receive the subsequent wayfinding instruction. Essentially, one needs to define the user's involvement for the different activities to be performed during a task. An example of a system that advocates both immediate support and spatial learning is GazeNav, a novel gaze-based approach for pedestrian navigation [16]. It communicates the route to take based on the user's gaze at a decision point. More specifically, navigation information is provided if the street the user looks at is the one to be followed. GazeNav allows for hands-free navigation, without any need to direct the visual attention away from the environment and back to a mobile device.

Future work in this area must focus both on the investigation and implementation of features and processes that stimulate spatial learning, as well as on their empirical evaluation. Application features could be intrinsic to the mobile decision-making process, either static and prescribed by the system (e.g., required landmark matching), or dynamic through automatic system recognition of a user's unawareness of the environment. Another possibility consists in adding features to foster spatial learning after task completion, such as having the user review the taken route on a map or sorting photos taken at intersections along the route in the order they occurred in the environment. Empirical studies are required to evaluate the impact of these features on users' spatial learning. For example, the described GeoGazemarks concept augments people's spatial memory to facilitate orientation but it is not clear whether this has a negative influence on their acquired spatial knowledge of the environment. Possibilities for testing such knowledge consist of post hoc distance and direction judgments, or having the users draw sketch maps and compare these to the actual environment.

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