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Experiences from the Use of an Eye-Tracking System in the Wild

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ABSTRACT
Eye-tracking systems have been widely used as a data collection method in the human–computer interaction research field. Eye-tracking has typically been applied in stationary environments to evaluate the usability of desktop applications. In the mobile context, user studies with eye-tracking are far more infrequent. In this paper, we report our findings from user tests performed with an eye-tracking system in a forest environment. We present some of the most relevant issues that should be considered when planning a mobile study in the wild using eye-tracking as a data collection method. One of the most challenging finding was the difficulty in identifying where the user actually looked in the three-dimensional environment from the two-dimensional scene video. In a concrete matter that means it is difficult to assure whether the gaze is directed to an object short of the user or to a distant object that is partly occluded by the closer one.

1. INTRODUCTION
According to Renshaw and Webb [10], the benefits of eye-tracking include the independence of data from user memory, the eliciting indication of problem solving strategies and a large amount of quantitative data. Examples of situations where the use of an eye-tracking system would be useful are when there is a need to get information about the most important objects used in navigation or to identify which objects in traffic a driver of a car notices and misses. In addition to eye-tracking, other methods such as interviews, observation and performance accuracy are applied to validate or to complete the findings observed in the eye-tracking data.

Another issue is the need to research mobile user experience in the field instead of the laboratory. For example, Nielsen et al. [8] stated that the field setting elicits a significantly increased amount of usability problems, as well as problems with interaction style and cognitive load that are not identified in the laboratory setting. If the research target is to investigate wider user experience in a natural context as well as to identify usability problems, the importance of a field study is even more evident.

The use of eye-tracking systems has been very sparse in the research of mobile user experience. Along with stationary environments, they have been used for example in the research of shopping behaviour, infants' natural interactions, and various everyday tasks [2][4][5]. To our knowledge, the research of mobile user experience in a forest environment is virtually non-existent.

In this paper, we focus on using an eye-tracking camera in a typical Finnish rural environment – a forest. The emphasis of the experiments is more in the validity testing of the eye-tracking method in user tests than in the use of mobile devices in order to discover the issues that must be considered when planning eye-tracking tests in the wild.

2. TESTS IN THE WILD
We executed multiple pilot eye-tracking tests in a forest environment with different tasks in different conditions. The eye-tracking system we used was iView X™ HED from SensoMotoric Instruments. This monocular system consists of an eye camera and a scene video camera which are attached to a bicycle helmet. The first tests were executed without a mobile phone. In that phase, the goal was to assess the feasibility of using an eye-tracking system in a forest environment and to pilot test task settings for future studies. During the tests, we took the users to the forest area to do simple navigation tasks. The tasks included, for example, walking through a certain route with a little guidance (no maps, paper or mobile applications were used), describing what he or she saw, describing how he or she located him/herself and describing the route in such a way that another person could follow it.

After completing the first experiments, a test with a mobile map service was executed. In this single experiment, the user walked a route according to given instructions and located herself on the map. The user was also asked to navigate on foot to a certain position pointed on the map. The composition of the test is presented in Figure 1.

In addition to recording eye-tracking data and interviewing the user during the test situation, the users were interviewed after the tests as well. These post-experiment interviews were conducted to validate and complete the eye-tracking data and observations made in both of the field test cases.

Figure 1. The goals of the test tasks were to resolve the current location on the mobile map and to navigate to a predefined position. The eye-tracking camera was attached on the bicycle helmet and the laptop used for data recording was carried in the backpack.

3. CHALLENGES

In this section, we present the main findings of using an eye-tracking system in a mobile context.

Some problems concerning the use of eye-tracking systems are commonly recognised in stationery environments. Those issues include, for example, the difficulties of tracking a person's eye movements if he or she wears glasses, if his or her pupil size is very small (e.g. when tired), the colour of iris is tepid or if the person has very long, downward or made-up eyelashes [3].

Along with these problems, we also discovered some special issues that should be considered when conducting eye-tracking research in a mobile context.

3.1 Data Quality

There are some issues in using an eye-tracking system in the wild that may risk the quality of data. Perhaps the most challenging issue in executing an eye-tracking test in a field setting is that the off-the-shelf eye-tracking systems are unable to provide definite information about distance of focused gaze in three-dimensional environment [9]. The monocular system we used provides data consisting only of gaze cursor on the recorded scene video, that is gaze position relative to the head (and video frame) [7]. Therefore, we faced situations where we could not be sure whether the user focused his or her gaze on a tree three meters ahead or to the lake that could be seen between the branches of the tree.

Few commercial binocular eye-tracking systems are available such as NAC Image Technology's EMR-9, which has some parallax error compensation. In addition to these, different labs using eye-tracking methodology have been developing eye-tracking systems that resolve the parallax problem and head movement both in natural environment and virtual reality [9][11]. One solution to this problem is the use of thinking-aloud. In addition to the lack of head tracking and depth information, the features of a forest environment make it difficult to define explicit areas-of-interests on recorded scene video data.

Calibration of an eye-tracking camera is much more difficult in the mobile context than in stationary conditions. In a mobile context, especially when investigating mobile device use, the gaze distance varies from couples of dozen centimetres to hundreds of metres. However, the gaze data is the most accurate at the calibration distance due to parallax errors [7]. We handled the calibration by using a large rectangular area, wall or a large paperboard several metres away from the user in the same environment that the test was going to occur. The calibration was then tested by comparing the equivalence of what the video showed and what the user said he or she was looking at. Generally, the calibration needed to be corrected several times. We discovered that calibration should be repeated during the test because it quite easily weakened in motion even though the helmet with the eye-tracking camera was strapped very tight.

Due to the unreliability of the calibration and parallax errors the eye-tracking system may not be trustworthy enough to examine eye movements in the mobile device's small screen. However, the eye-tracking system is very suitable for tracking when, in which situations and for how long a user takes the mobile device in hand and checks it for location or direction.

3.2 Experimental Conditions

Regarding the experimental conditions, the most obvious ones concern weather conditions, which differ from the stable environment of a research laboratory. It is important to take into account that, for example, rain may prevent executing the tests at the planned time. The use of eye-tracking cameras also requires adequate light, thus, it is typically also impossible to execute tests early in morning or late in the night – at least in the winter time. Moreover, the lighting conditions may vary during one single experiment session.

Wearing a helmet or other attachment object with an eye-tracking camera, which has multiple hanging wires, and carrying a laptop in a backpack or a shoulder-case handicaps the movements of the user and influences his or her behaviour, at least until he or she gets used to the equipment. For that reason, it is recommended that the actual test is not performed until the user has had some time to become familiar with the equipment. Improvements to the mobility of eye-tracking systems are being made, but to the best of our knowledge, the current solutions are not yet unobtrusive to the user. For example, in 2008, a research executed with a new kind of eye-tracking solution, light-weighted EOG goggles, was reported by Bulling et al. [1], but also in that solution the user has to carry a laptop with him or her. On the other hand, Tobii Technology has recently introduced Glasses Eye Tracker, which uses smaller recording unit instead of a laptop.

One limiting factor in eye-tracking tests in the mobile context is the low battery capacity that applies to many eye-tracking systems. Keeping that in mind, it is impossible to plan a user test that would last for hours. With our test equipment, the maximum duration for test recordings was about half an hour. The weather conditions (e.g. cold or hot) as well as the bag for the recording laptop also influence this factor.

Finally, it is essential to pay attention to the careful design and definition of test tasks in order to be aware of the user's goals and to interpret the gaze data [5].

3.3 Underlying Cognitive Processes

One should be aware that eye-tracking data does not give all-encompassing data of the allocation of the user's attention. Eye movements can be an indication of a shift in attention (overt attention); on the other hand, a user may shift his or her attention to another target without moving his or her eyes (covert attention) [6]. In our study, the dissociation between where user looked and what she paid attention to was evident in the picture recognition test as well. After the user had walked the route in the forest, she was asked about what she saw and was then shown pictures and asked to decide whether they were taken of the route. The user was shown 16 pictures, of which five were from the route (see example in the Figure 2) and nine were from other forest scenes. The recognition rate was very low; only a couple of the pictures were recognized properly. The results of our recognition test cannot be completely trusted though because they are based on a very small amount of data.

Figure 2. One of the pictures used in the recognition test. The task given to the user after walking a certain route in the forest was to identify whether the shown pictures were taken on the route.

4. CONCLUSIONS

Despite the many challenges of using eye-tracking systems in a mobile context, they provide a valuable method for gathering data that could not be reached by any other method; for example, behavioural methods such as think-aloud verbal reports and reaction-time-based methods lack the kind of data that can be gathered by eye-tracking solutions. The problematic issues presented should be considered when preparing a test with an eye-tracking system in the wild. Some of the issues, such as the weather and light conditions, are easy to take into account. Instead, some of the problems identified in this study, such as the difficulties of defining area of interests in three-dimensional data, should be reacted by the eye-tracking systems' manufacturers.

This paper is in a state of a position paper and many of the presented findings still require validation.

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6. REFERENCES

[1] Bulling, A., Roggen, D., and Tröster, G. 2008. It's in your eyes: towards context-awareness and mobile HCI using wearable EOG goggles. In *Proceedings of the 10th International Conference on Ubiquitous Computing* (Seoul, Korea, September 21-24, 2008).

[2] Castagnos, S., Jones, N., and Pu, P. 2009. Recommenders' influence on buyers' decision process. In *Proceedings of the Third ACM Conference on Recommender Systems* (New York, USA, October 23-25, 2009).

[3] Duchowski, A. T. 2007. *Eye Tracking Methodology: Theory and Practice.* London: Springer-Verlag.

[4] Franchak, J. M., Kretch, K. S., Soska, K. C., Babcock, J. S., and Adolph, K. E. 2010. Head-Mounted eye-tracking of infants' natural interactions: A new method. In *ETRA '10: Proceedings of the 2010 symposium on eye-tracking research & applications.* ACM.

[5] Hayhoe, M. and Ballard, D. 2005. Eye movements in natural behavior. *Trends in Cognitive Sciences*. 9, 4, 188-94.

[6] Henderson, J. M. 2003. Human gaze control during real-world scene perception. *Trends in Cognitive Sciences.* 7, 11, 498-504.

[7] iView X System Manual. Version 2.2. SensoMotoric Instruments.

[8] Nielsen, C. M., Overgaard, M., Pedersen, M. B., Stage, J., and Stenild, S. 2006. It's worth the hassle!: the added value of evaluating the usability of mobile systems in the field. In *NordiCHI '06: Proceedings of the 4th Nordic Conference on Human-Computer Interaction* (Oslo, Norway, October 14-18, 2006).

[9] Pfeiffer, T., Latoschik, M. E., Wachsmuth, I., and Herder, J. 2008. Evaluation of binocular eye trackers and algorithms for 3d gaze interaction in virtual reality environments. *Journal of Virtual Reality and Broadcasting*, 5, 16.

[10] Renshaw, J. A. and Webb, N. 2007. Eye tracking in practice. In *Proceedings of the 21st BCS HCI Group Conference HCI 2007* (Lancaster University, UK, September 03-07, 2007).

[11] Wagner, P., Bartl, K., Günthner, W., Schneider, E., Brandt, T., and Ulbrich, H. 2006. A pivotable head mounted camera system that is aligned by three-dimensional eye movements. In *Proceedings of the 2006 symposium on eye tracking research & applications.*