Eye movements when using a camera phone to search on wall maps

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Introduction

Most current mobile phones are equipped with cameras that not only allow the user to take snapshots, but can be deployed as an input device for more sophisticated applications like superimposing additional information on the image displayed on the mobile phone display. Maps for example could thus be dynamically enriched with information necessary for the task at hand using the mobile phone as a 'magic' reading glass or lens (Bier et al., 1993, see also figure 1). However, it is not clear to what extent the users actually switch between both layers of information, the map in the background and the map snippet shown on the mobile phone display.

Motivation

A previous study suggested that with increasing numbers of items, subjects tend to focus on the mobile phone display alone and search became less effective due to difficulties memorizing all available information (Rohs et al., 2009). **The goal of this study was to examine whether**

- an additional 'clipboard' functionality could decrease the memory load and lead to better search results.
- extending the dynamic information display onto the background map would have an effect.
- search performance shows any relation to the usage of both layers (background map and phone display) of information.

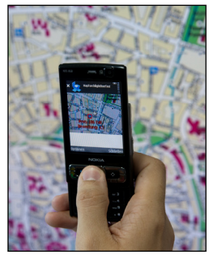

Figure 1: Magic lens interface *mobile phone display shows additional information on camera image of wall map.*

Materials and design

Task: find the cheapest hotel that has a user rating of 3.5 or higher on the map.

Stimulus material: city map of a German city (Münster) with randomly placed hotel symbols maps displayed on a HDTV-screen (Barco LCN-42 LCD screen 42", 1920x1080 pixels, 934x527 mm). Position of hotels on map changed per trial.

Nokia N95-8GB camera phone recording search time and hotel selection

Experimental variation: number of hotels to search on the map [2, 4, 8, 16] and availability of clipboard functionality i.e. possibility to keep price & rating of 1 hotel in memory and re-check it on phone display

4 mobile phone interfaces:

- magic lens: phone display shows camera image of map with superimposed price & rating no clipboard functionality (see figure 1).
- clipboard+halo: position of hotel stored in clipboard is marked with a yellow halo visible on phone display.
- clipboard+marker: position of hotel stored in clipboard is marked with a blue circle on background map (see figure 2).
- clipboard+halo+marker: both marker types (phone display and background map) present.

Order of interface presentation and hotel set size within an interface block randomized, 4 trials per condition x 4 different hotel set sizes x 4 interface types = **64 trials per subject**.

Figure 2: clipboard with marker (screenshot from eyetracking video): *position of hotel stored in clipboard is marked with a blue dot on wall map.*

Participants: 20 students, (13 male) age= 24.8 ± 2.6, paid 15€ for participation; recordings of 3 users (2 male) had to be excluded from further analysis due to low data quality.

Data Collection & Processing

Eyetracker: head-mounted Eyelink II eyetracker (SR Research) recording eye movements binocular with a sample rate of 250 Hz as well as video of visual scene with overlayed gaze. Calibration on wall map HDTV display, leading to pixel coordinates of gaze direction. Automatic identification of saccades and fixations using built-in parser.

Gaze shifts: differences in x-coordinates of left and right eye were used to determine visual depth plane, i.e. gaze on wall map or mobile phone display. Individual thresholds were obtained by examining x-differences of current fixations in relation to amplitude of previous saccade (larger saccades on wall map compared to small mobile phone display where only saccades < 7°were possible). Thresholds were cross-checked with video recordings of visual scene and overlayed eye movements.

Baseline-correction pupil dilation: pupil dilation of each fixation baseline-corrected with average pupil dilation during first 5 seconds of the first trial for each interface block.

Stasticial analysis: all statistical analyses were done with mixed models (repeated measurements) function in SPSS 16.

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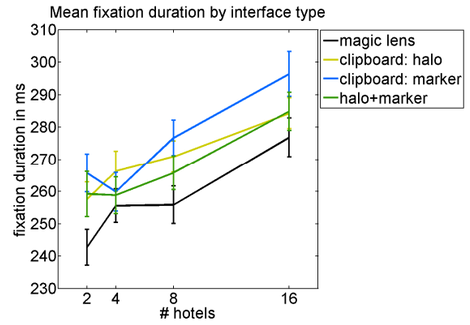
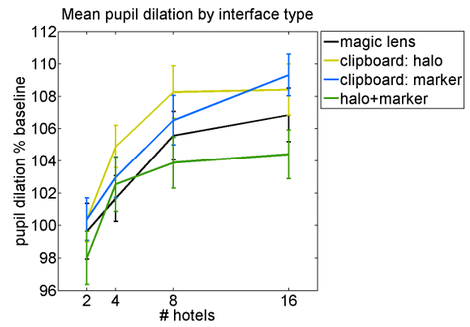
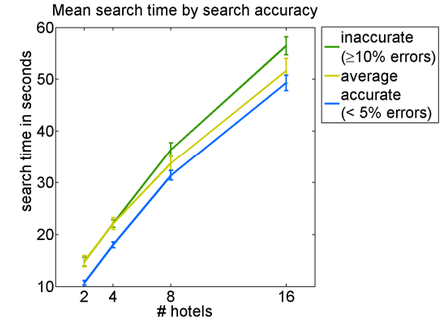
Results

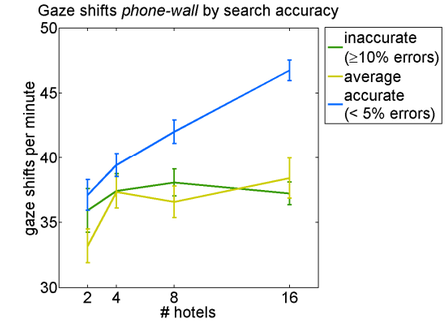




Analysis by interface type:

- **mean fixation duration** (left plot) increases with number of hotels to search ($F_{3, 926}$=16.223; p<0.00) as does search time ($F_{3, 912}$=640.06; p<0.00) and number of errors ($F_{3, 521}$=7.034; p<0.00); no significant effect of interface type for all three parameters ($F_{3, 261}$=2.002; p=0.1; $F_{3, 247}$=0.991; p=0.4 and $F_{3, 316}$=0.964; p=.41),
- **mean baseline-corrected pupil dilation** (right plot) increases with number of hotels to search ($F_{3, 940}$)= 53.880; p<0.00), and with interface type ($F_{3, 766}$)=2.919; p=0.03). Pairwise comparison shows significant difference of marker and halo+marker interface (p=0.029, Sidak-adjusted)





Analysis by search performance: 'accurate' (<5% error trials) vs. 'inaccurate' (>10% error trials) searchers:

- **accurate searchers** also **search faster** (left plot) ($F_{2, 132}$=11.722; p<0.00), no significant effect of interface type ($F_{3, 229}$=0.879; p=0.45), but general effect of number of hotels ($F_{3, 820}$=646.962; p<0.00)
- **accurate searchers** show increasingly **more gaze shifts** (right plot) between mobile phone and wall map than inaccurate searchers with increasing number of hotels ($F_{3, 261}$=16.223; p<0.00), no significant effect of interface type ($F_{3, 248}$=1.972; p=0.12), but general effect of number of hotels ($F_{3, 570}$=6.609; p<0.00)

Discussion & Conclusion

The main influence on search performance and mental workload (indicated by fixation duration and pupil dilation) in this search task was the number of items, the availability of a clipboard functionality to store possible targets appeared to be less important.

However, the implementation of a clipboard with halo+marker showed some advantage over all other variations with regard to pupil dilation. Here, extending the information on the background was only useful if the information is available on the phone display as well. Subjective ratings (not given in results section) indicated that subjects slightly preferred the 'marker on wall map' followed by the combination of both marker and halo.

Accurate search appeared to go along with frequent gaze shifts between mobile phone display and wall map. A future interface should probably target at encouraging these switches or provide an optional tutorial how to use it most efficiently.

Literature

Bier, E. A., Stone, M. C., Pier, K., Buxton, W.,& D., D. T. (1993). *Toolglass and magic lenses: The see-through interface.* SIGGRAPH '93 (pp. 73-80): ACM.
Rohs, M., Schleicher, R., Schöning, J., Essl, G., Naumann, A.,& Krüger, A. (2009). Impact of Item Density on the Utility of Visual Context in Magic Lens Interactions. *Personal and Ubiquitous Computing (PUC), 4*, 1617-4917.