Combining wearable eye-tracking with 4π light-field measurements: towards controlling all bottom-up and top-down factors driving overt attention during real-world tasks

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Introduction

For improvement of office space design, we intend to capture the full (4π) light-field of an office space, while measuring gaze, head direction, body position, blink rate, and pupil size along with task performance and subjective well-being during a variety of office tasks. Besides the immediate application aspects this will allow for the first time to have full control over task and visual input in a fully unconstrained real-world setting.

In the study reported here, 52 participants performed office tasks that varied in the tools used (phone, computer, paper) as well as in their mental load – input, output, reflection and interaction – and were recorded under various experimentally controlled lighting conditions and outside views. We analyze gaze allocation during these tasks, with a particular emphasis on the distinct roles of eye and head, as well as on the effects of discomfort glare.

Real-world Setup

A: HDR-photo from test room arranged alike a regular office environment.

B: Participant during measurement.
Above its head: 2 LMK luminance cameras.

C: A comfortable unobtrusive gaze-tracking device (*"EyeSeeCam"*) records eye- and head-movements at 221Hz.

Our measurement facilities are located in Freiburg (South Germany) on top of the four-storey Fhg ISE main office building. The test room measures 3.5 x 6 x 3 meter and can be fully rotated around 360°.

Glazed façade specs: color-neutral, double glazing, Tvis = 0.54, U-value = 1.1 W/m#K, g-value = 0.29.

For daylight control, the rooms are equipped with Venetian blinds, roller blinds and foil. A meteorological station on the roof of the test rooms records the global, total and diffuse illuminance [lux], as well as the global horizontal irradiance [W/m2]) .

Varaying outside views,
Up: south-west orientation,
Down: west orientation

Paradigm

Here, 2 different views were chosen as independent, between-subject variable, all independent of the weather. The experimental design further includes two independent, within-subject variables, namely 3 different task supports which are subdivided into 4 office tasks. Employees and students at the ISE Fraunhofer institute took part of the experiments (age 18-59, mean 29.2, std 7.9 years).

Every participant was asked to sit in a single room on an office workplace to execute various office tasks at a computer, on a paper print and during a phone call after each other, with four action blocks in a cyclic sequence. Task order for computer, paper and phone was randomized for each subject. The first block was receiving a text, followed by a block for "thinking about it". A multiple choice questionaire related to the text was posed in the third block and had to be answered subsequently. In the last block, an opinion should be given onto a question regarding the actual text.

Details: SAREY KHANIE, M. ANDERSEN, M. 't HART, B. STOLL, J. EINHÄUSER, W. 2011. Integration of Eye-tracking Methods in Visual Comfort Assessments.CISBAT 11: CleanTech for Sustainable Buildings - From Nano to Urban Scale, Switzerland. Lausanne. 14-15.

Eye to Gaze Coordinates transformed by Head Orientation

A mobile eye-tracker equipped with an inertia measurement unit (IMU) records eye-in-head plus rotating and translative head movements and a scene video.
Integration in quaternion formalism of calibrated rotation velocities yields head orientations time series, whose room referencing is applied by measuring a few scene-camera images.

Eye-in-head angles are rotated for room referencing by the sideward's head tilt and then superposed straightforward with head in room orientations into room referenced gaze directions.

Detailed method's link:

https://www.dropbox.com/s/os3xdvaeaago7bf/measHeadNGazeOrientations.pdf

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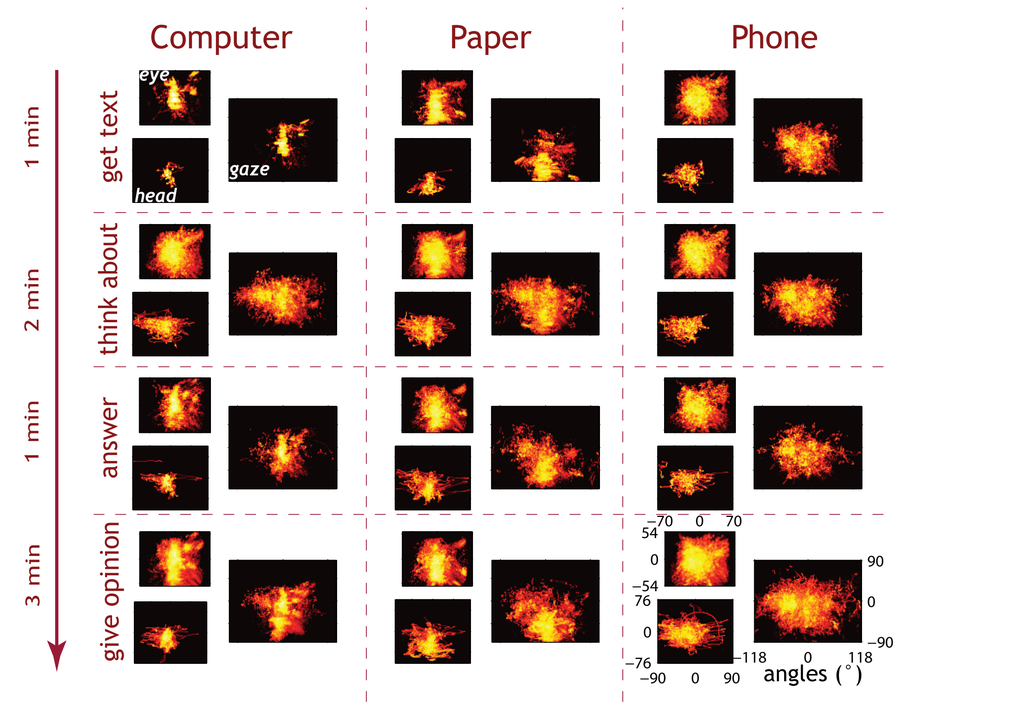
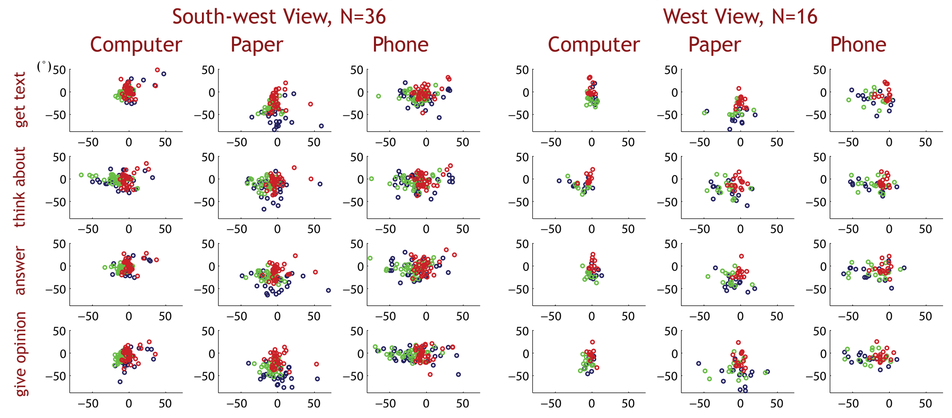
Results

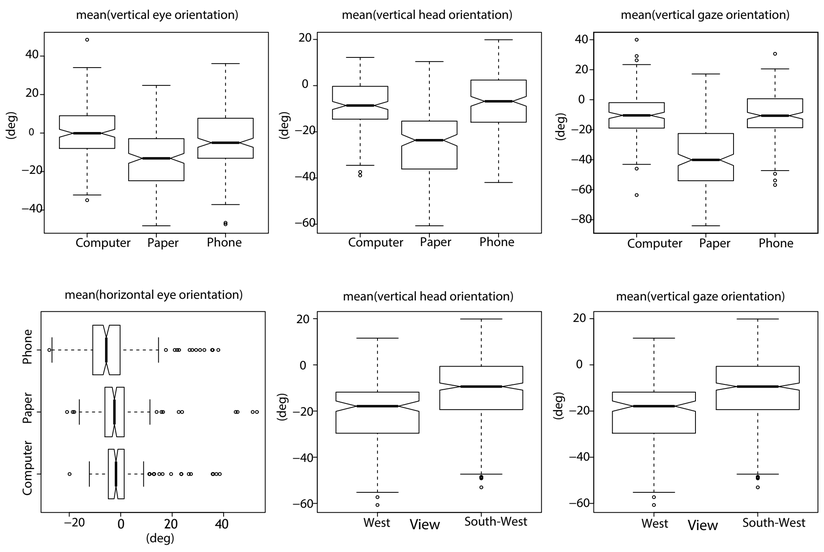
Distributions of ***Eye-in-Head***, ***Head-in-Room and Gaze-in-Room*** orientation (horizontal and vertical angles). Grand mean, N=52. Data are separated by the independent variables office task (4 rows) and task support (3 columns). Eye-, head- and gaze distributions are scaled equally.



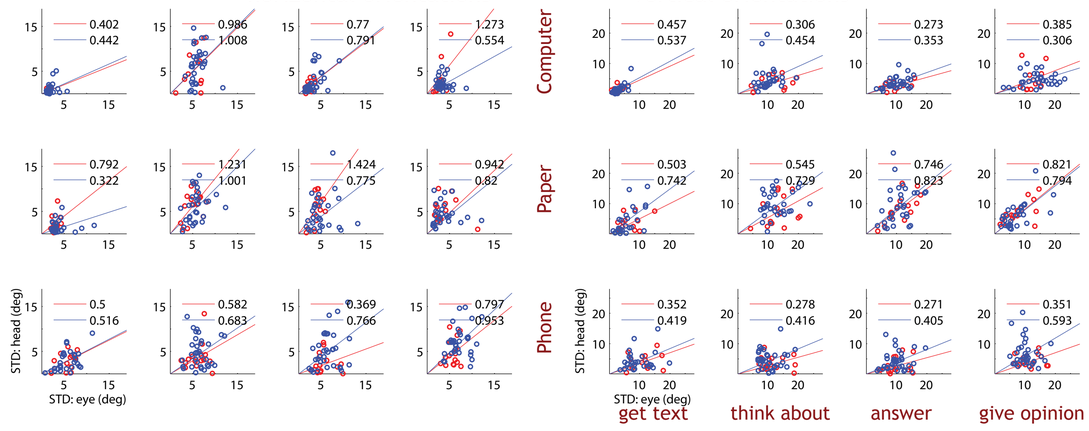
Individual means over horizontal against vertical angle coordinates separated by view (left and right half) as well as task and block. ***Eye***-, ***Head***- and ***Gaze*** measures are colorcoded in red, green and blue respectively.



Mean Eye, Head and Gaze orientations in boxplots; left, middle and right, respectively.
Most significant effects between office support:
Eye: vertical - F 3.9, p 0.028
Eye: horizontal - F 3.9, p 0.028
Head: vertical - F 6, p 0.005
Gaze: vertical - F 8.6, p 0.0008
Effects on View:
Head: vertical - F 12.5, p 0.001
Gaze: vertical - F 4.4, p 0.043



Individual standard deviation from Eye and Head orientations scattered against each other separately - view colorcoded: ***West***, ***South-West***. Mean and regression values vary consistently with tasks and views: Reading lowers eye; thinking boosts head!



Conclusions

We find that eye and head are fundamentally differently affected by view as well as depending on mental activity and task conditions, even for the reading task. Surprisingly, gaze allocation is not dominated by eye movements, but for some tasks head movements, which are not typically assessed in standard laboratory experiments of attention deployment, play a dominant role.

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