Eye tracking in virtual 3D environments: Challenges and directions of future research

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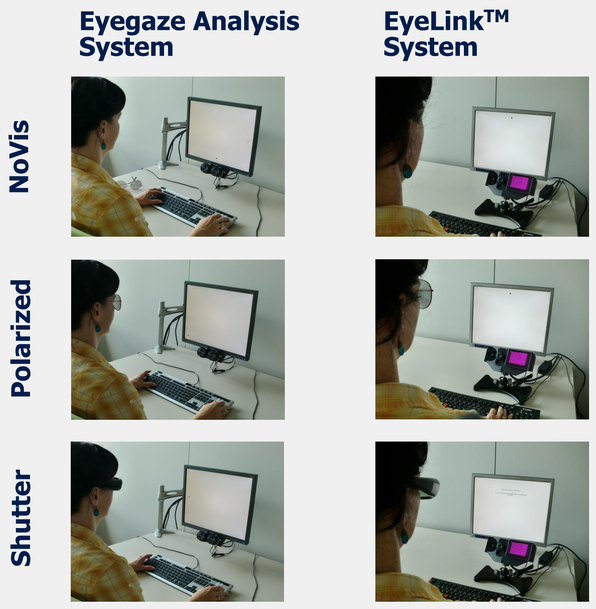
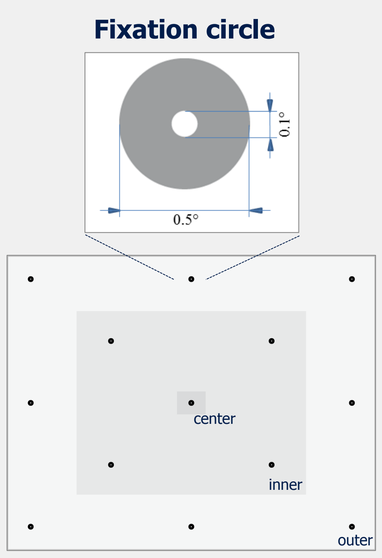
Introduction

Current stereoscopic visualization technologies allow for a realistic presentation of objects and scenes. Virtual reality environments are broadly employed in the entertainment industry (Nguyen et al., 2005), e-learning (Monahan, McArdle, & Bertolotto, 2008) and used for simulation (Velichkovsky, Rothert, Kopf, Dornhoefer, & Joos, 2002). Moreover there is increasing interest in understanding how visual attention is distributed in simulated dynamic settings, e.g. for diverse medical applications (Burgert et al., 2007). For such studies, eye tracking provides the essential technology (Hayhoe & Ballard, 2005) but is limited by the fact that current algorithms are optimized for 2D settings.

The aim of this study was to combine 3D visualization technologies with eye tracking. Therefore, we examined if the employment of 3D glasses (polarized filter and shutter glasses) interferes with the recording of 2D eye tracking. Furthermore we investigated possible influences of visualization techniques on the accuracy of recorded sample data, fixations and pupil sizes in different environments.

Methods



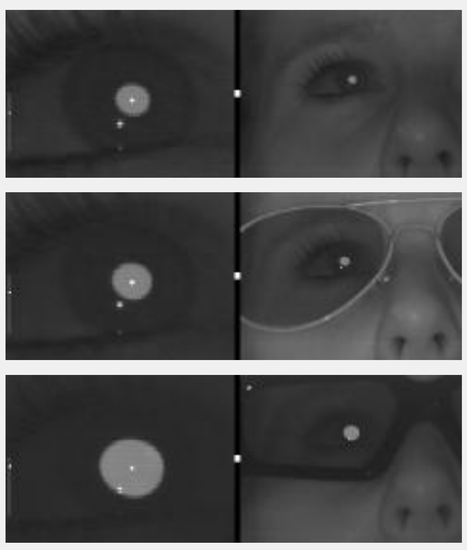


Positions and monitor areas

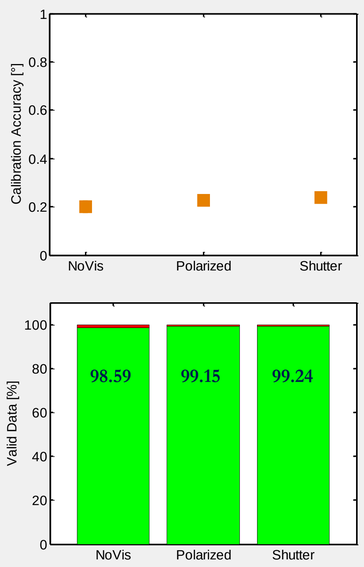
Participants	12 volunteers (8 female), mean age 26 years
Remote eye tracker	Eyegaze Analysis System, LC Technologies, Inc. - binocular, bright pupil, 120 Hz EyeLink™ System, SR Research - monocular, dark pupil, 500 Hz
Visualization technologies	linearly polarized filter glasses shutter glasses, NVIDIA® 3D Vision™
Fixation circle	displayed 10 times on 13 spatially balanced positions, display duration was 1000 ms for each fixation circle
3 visualization conditions	no visualization technology (NoVis), polarized filter glasses (Polarized), shutter glasses (Shutter)
3 area conditions	center, inner, outer
Objective measures	calibration data, sample data, fixations, pupil sizes

Results

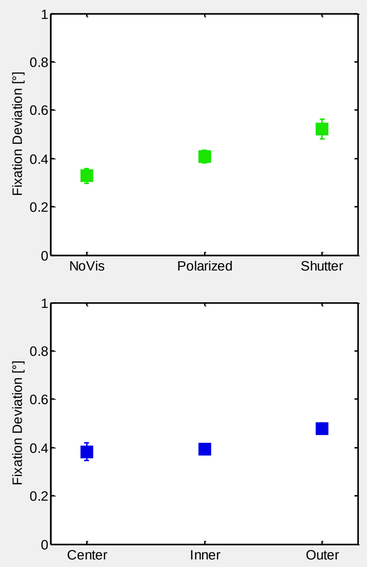
Eye images



Calibration / valid data



Fixation accuracy



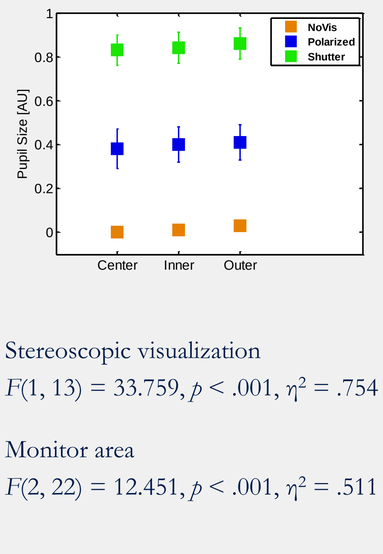
$F(2, 22) = 11.130$, $p < .001$, $\eta^2 = .503$

$F(1, 13) = 7.613$, $p = .003$, $\eta^2 = .409$

$F(2, 22) < 1$

$F(2, 22) = 20.109$, $p < .001$, $\eta^2 = .646$

Pupil size



Stereoscopic visualization
$F(1, 13) = 33.759$, $p < .001$, $\eta^2 = .754$

Monitor area
$F(2, 22) = 12.451$, $p < .001$, $\eta^2 = .511$

Stereoscopic visualization
$F(1, 15) = 39.691$, $p < .001$, $\eta^2 = .783$

Monitor area
$F(1, 15) < 1$

Discussion

(1) No differences in accuracy of calibration data over all conditions.
(2) Constant proportion of valid samples also using virtualization technologies.
(3) Sample data and fixation deviation: Eyegaze Analysis System: less accuracy in Polarized, Shutter, Inner, Outer; EyeLink System: less accuracy in Inner, Outer
(4) Fixation positions are more precise than Sample data.
(5) Pupil sizes increase in filter conditions.

Our results demonstrate the feasibility of combining eye tracking with visualization techniques (polarized filter and shutter glasses). However, 3D visualization technologies influence the accuracy of recorded gaze data. We found an increase in the deviation of sample data (< 0.2°), of fixation positions (< 0.1°) and enlarged pupil sizes up to 154 %. In future work, the current results will be used as a basis for the development of new 3D fixation and saccade detection algorithms.

References

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