Eye tracking in real world and virtual environments: Algorithms for determining gaze position in 3D space

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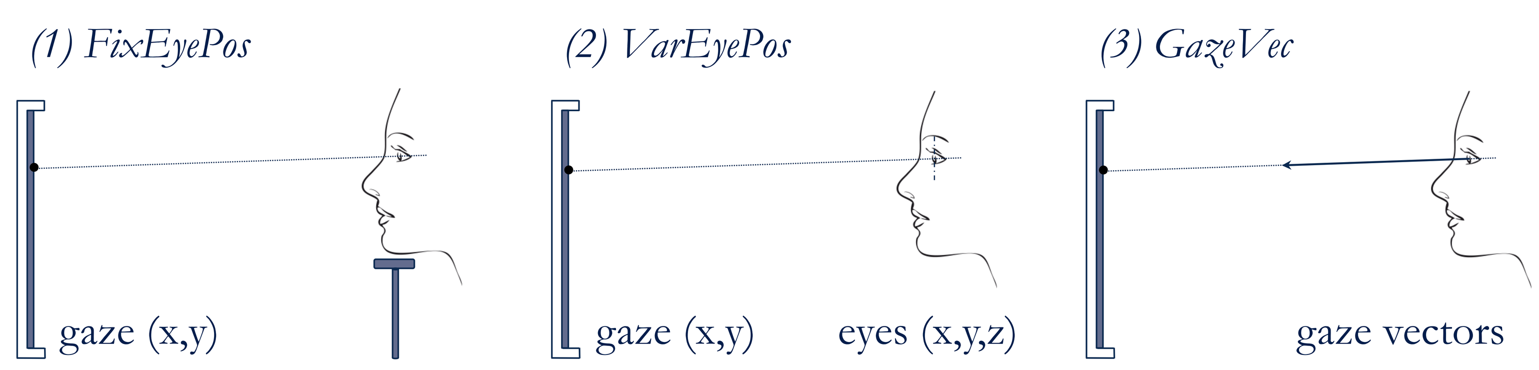
Introduction

In a previous study we combined 3D visualization technologies with eye tracking and examined if the employment of 3D glasses (polarized filter and shutter glasses) interferes with the recording of 2D eye tracking data. Furthermore we investigated possible influences of visualization techniques on the accuracy of recorded sample data, fixations and pupil sizes in different environments (Weber, Pannasch, Helmert, & Velichkovsky, 2011). In the current study we explored the calculation of 3D gaze positions based on different eye tracking output parameters in a real world setting and a virtual environment. Therefore, objects were presented in different depth planes within the measuring frustum of a remote eye tracking system while recording eye physiology and gaze data. We analyzed the deviation between the calculated 3D gaze position and fixation object, the accuracy of the depth parameter and the influence of the stimulus brightness of the fixation depth (Huckauf, Watrin, Yuras, & Koepsel, 2013). The results can be used to increase the accuracy in object selection by using the fixation depth information (Pfeiffer, Donner, Latoschik, & Wachsmuth, 2007) or for finding deviation thresholds for fixation detection in 3D space similar to the spatial 2D fixation detection algorithms (Komogortsev, Gobert, Jayarathna, Koh, & Gowda, 2010). In future work, the current results will be the basis for the development of a new 3D fixation detection algorithm.

Methods

We used different parameters of common eye tracking systems and calculated the minimum distance to both gaze vectors in order to obtain 3D gaze positions. The basic set of variables are the binocular (x,y) coordinates at the calibration plane, e.g. monitor screen. Therefore, subjects' eye positions have to be stable while measuring (1). With 3D eye positions provided by the eye tracking system, restriction of head movements is no longer necessary (2). And finally, 3D gaze can be obtained directly from eye tracker's gaze vector information (3).



Real World

Participants 12 volunteers (5 female), mean age 33 years

Remote eye tracker Eyegaze EyeFollower 2.0 System, LC Technologies, Inc. (binocular, bright pupil, 120 Hz)

Apparatus Plexiglas panel above the measuring area with guide devices to place 15 steal spheres in the 3D measuring area

Stimuli steal fixation spheres (Ø 7 mm), marked with a target, displayed on 45 (3x3x5) spatially balanced positions for a duration of 1000 ms

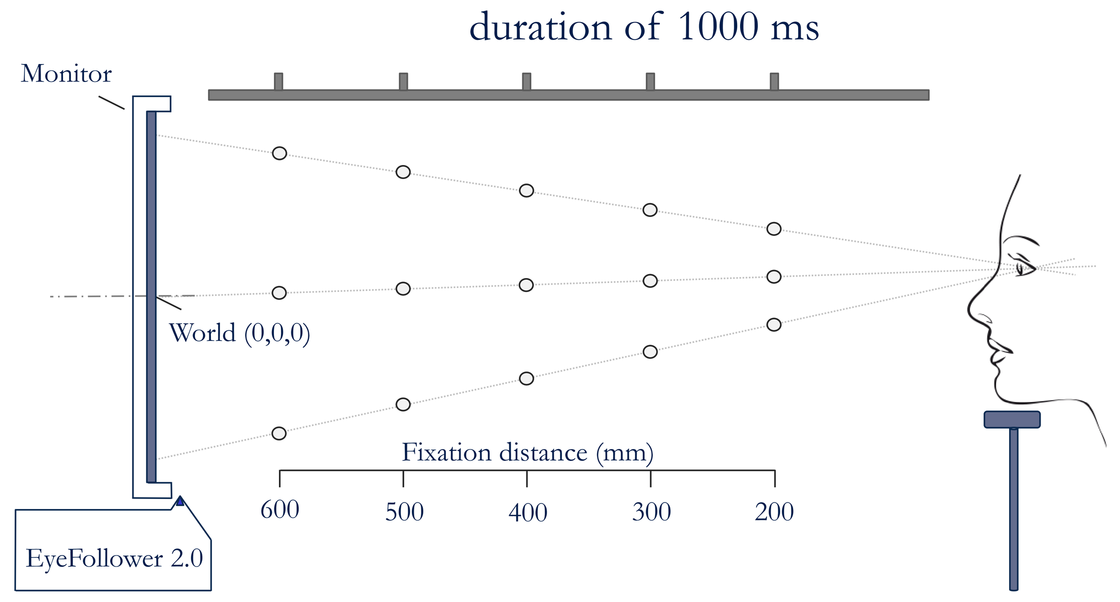
Virtual Reality

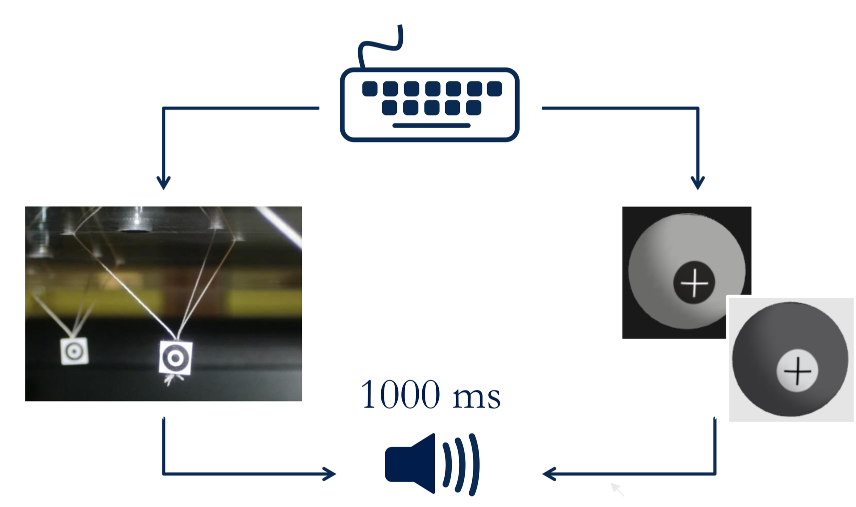
Participants 27 volunteers (12 female), mean age 32 years

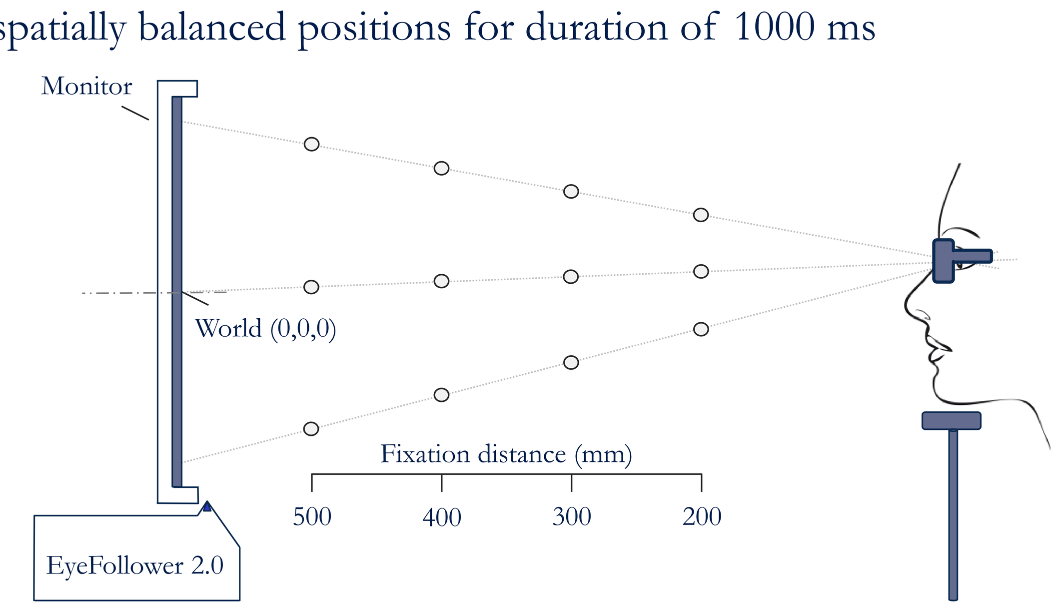
Remote eye tracker Eyegaze EyeFollower 2.0 System, LC Technologies, Inc. (binocular, bright pupil, 120 Hz)

Apparatus shutter glasses, NVIDIA® 3D Vision™ 3D monitor, ASUS VG236 (23.0", 120 Hz, RT 2 ms)

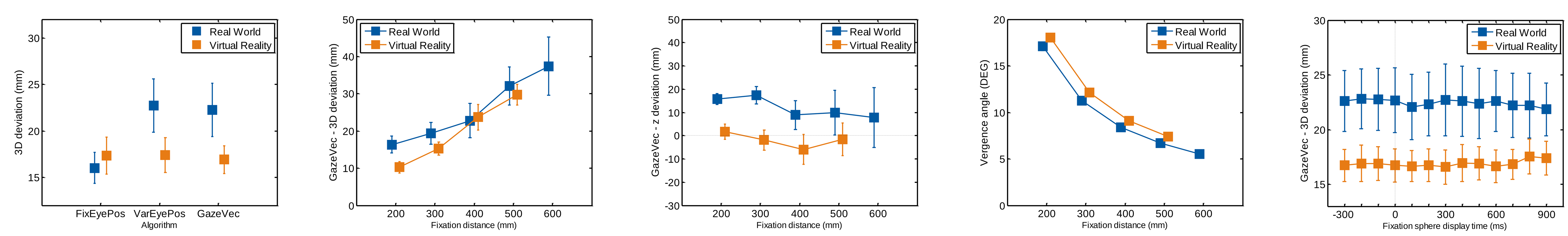
Stimuli dark and bright stereoscopic displayed fixation spheres (Ø 7 mm), marked with a target, displayed on 36 (3x3x4) spatially balanced positions for duration of 1000 ms







Results



$F(2, 22) = 37.839, p < .001, \eta_p^2 = .775$
$F < 1$

$F(4, 44) = 22.847, p < .001, \eta_p^2 = .675$
$F(3, 66) = 77.773, p < .001, \eta_p^2 = .780$

$F(4, 44) = 2.008, p = .110, \eta_p^2 = .154$
$F(3, 66) = 2.515, p = .066, \eta_p^2 = .103$

$F(4, 44) = 3763.103, p < .001, \eta_p^2 = .997$
$F(3, 66) = 5054.353, p < .001, \eta_p^2 = .996$

$F < 1$
$F(12, 264) = 1.674, p = .072, \eta_p^2 = .071$

Discussion

(1) Deviation results differ by the algorithms in Real World setting.
(2) The closer the distance to the fixation sphere, the lower the 3D gaze deviations.
(4) Depth parameter is more robust and the z-deviations are smaller than 3D deviations.
(5) Vergence angles for different distances are similar in Real World and Virtual Reality.
(6) No influence of the stimulus brightness of the fixation depth in Virtual Reality.
(7) The infrared light for eye tracking measurement decreases by using shutter glasses.

Our results demonstrate the feasibility of calculating 3D gaze in real world and stereoscopically displayed virtual environments. However, 3D deviations between gaze position and fixation object vary depending on the fixation distance. In virtual environments 3D deviations start to increase beyond 700 ms of fixation duration. Probably the accommodation-vergence conflict influences the fixation performance. The results will be the basis for the development of a 3D fixation detection algorithm.

References

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