Participants know best : The effect of calibration method on data quality

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Participants know best – the effect of calibration method on data quality

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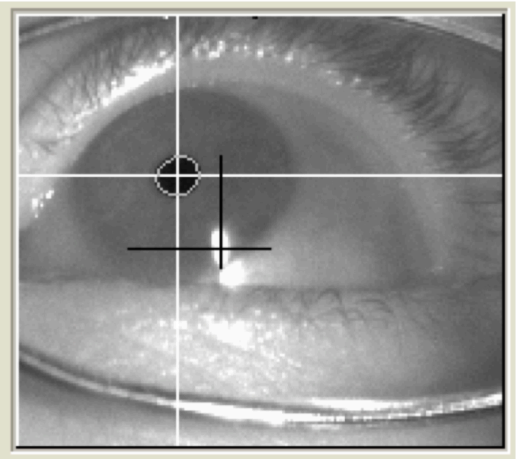
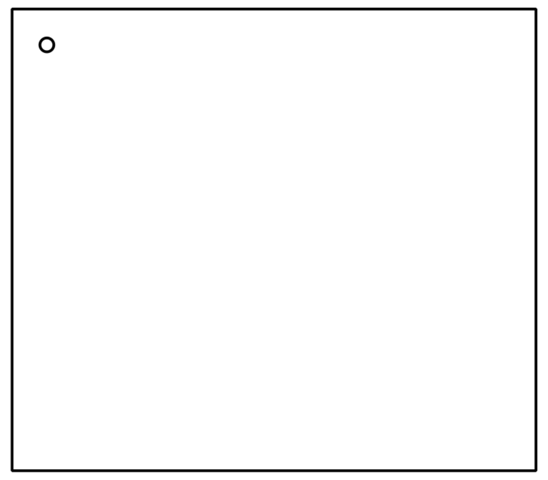
BACKGROUND

1. Automatic calibration
Software decides when eye feature samples are recorded.

2. **Operator-controlled**
The operator clicks a button to record eye feature samples.



Eye image with features
- Pupil (122.5, 147.7)
- Corneal reflection (201.3, 194.8)



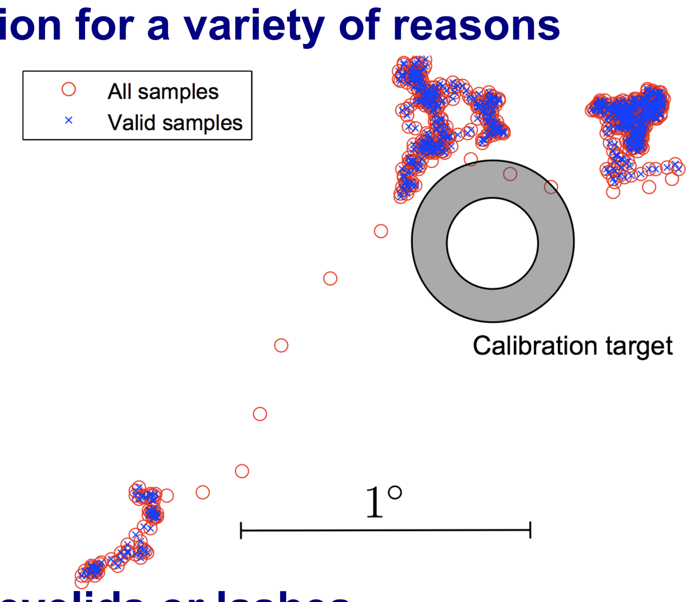
Calibration area with one target
- Target (21, 27)

3. **Participant-controlled**: The participant clicks a button to record samples.

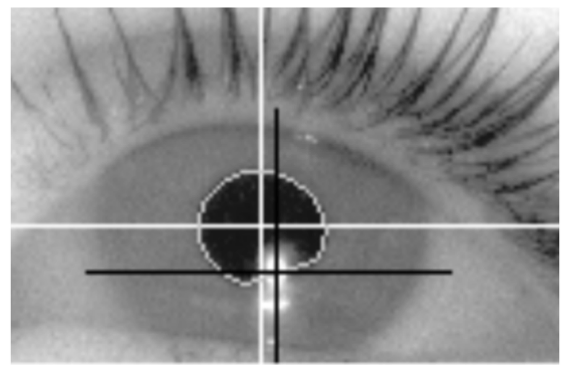
Challenges

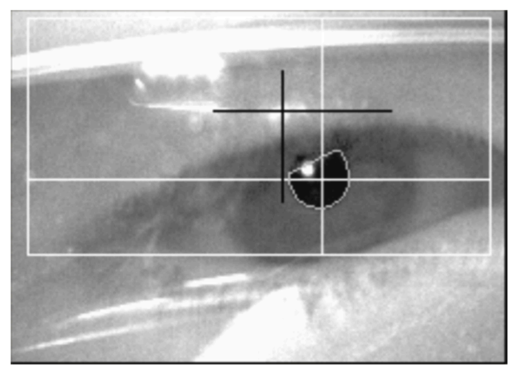
The participant must look straight at the calibration target, and keep the eye still. Also, optical conditions may confuse gaze the estimation algorithm.

***The participant* may move his eye during calibration for a variety of reasons**
- **Anticipation (looking ahead too soon)**
- **Square-wave jerks, glissades, blinks**
- **Distraction**
- **Poor task instructions**
- **Etc.**



***Gaze estimation* may be faltering due to**
- **Reflection in glasses**
- **Split corneal reflection in lenses**
- **The corneal reflection is in the sclera**
- **The pupil or corneal reflection are covered by eyelids or lashes**
- **Etc.**





METHOD

Data recording

Four stations with identical SMI HiSpeed 500 Hz binocular
Six operators (five experienced, one novice)
149 non-prescreened students of economics
Two recordings: Just after calibration, and after 15 minutes of reading.

Automatic (44), Operator-controlled (62), Participant-controlled (43)

Glasses (12), lenses (35), uncorrected vision (102)
Mascara (37), clean eye-lashes (112)
Dominant left eye (64), right eye (85)
Eye-lashes directed down (8), forward (32), up (109)
Eye cleft: medium (13), narrow (3), open (133)
Eye colour: blue (112), brown (35), quite other (2)

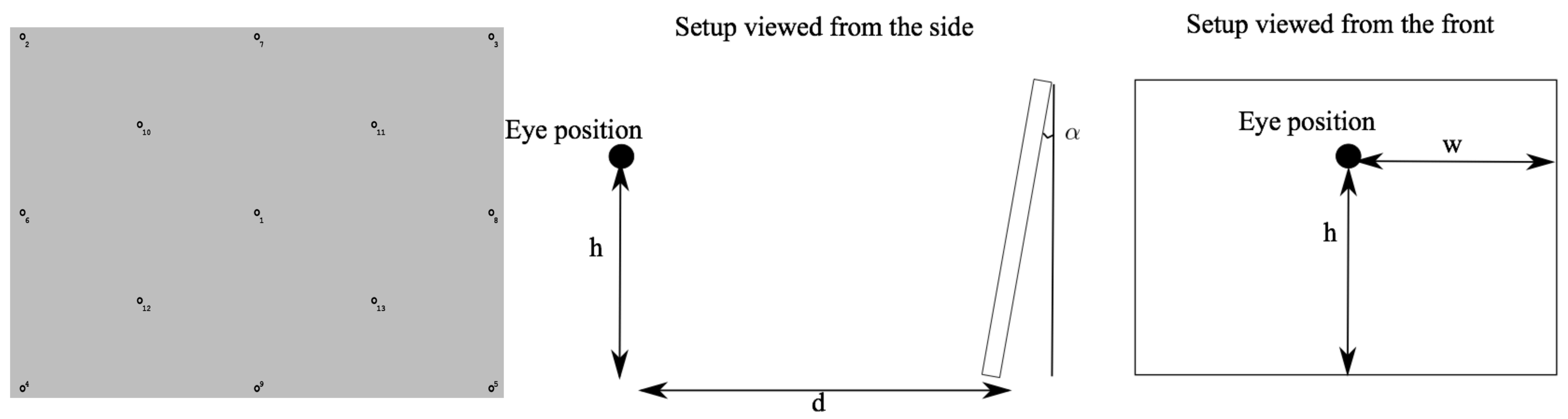
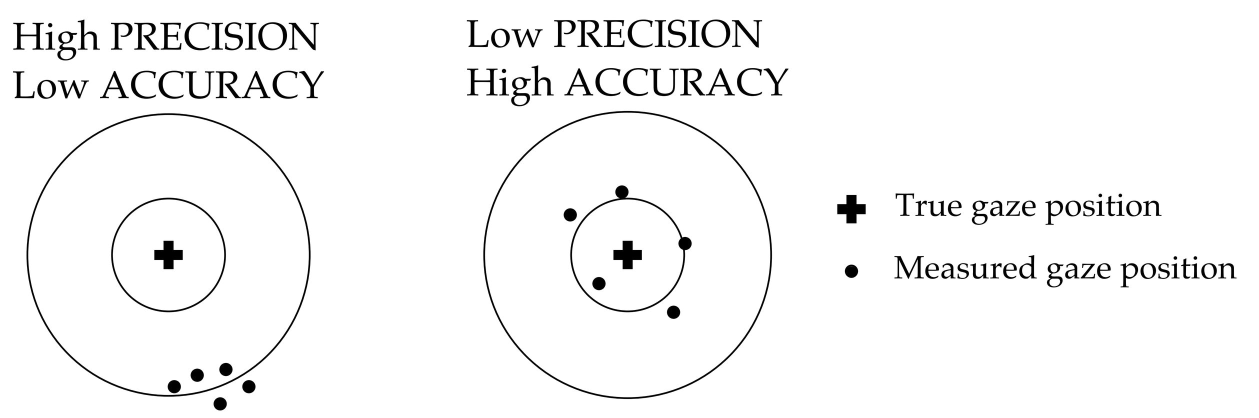


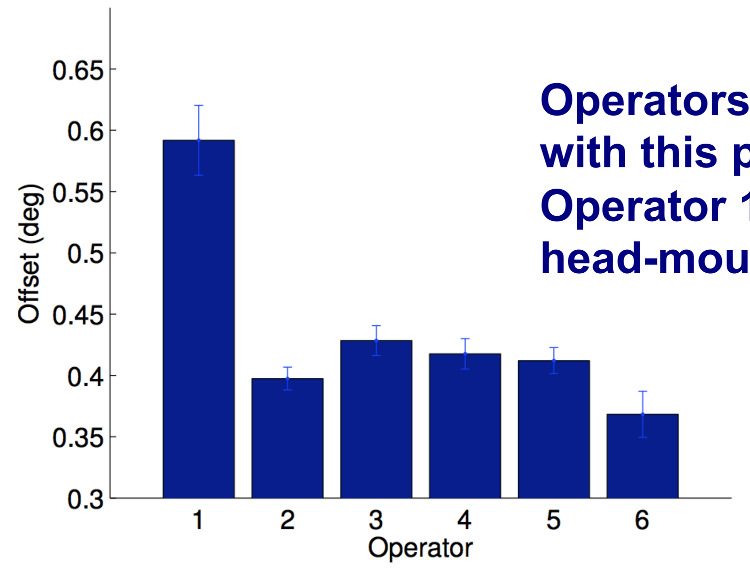
Figure 4: Experimental setup ($d = 670$ mm, $h = 670$ mm, $\alpha = x°$, $w = \frac{3}{4}\cdot$W mm, $h = \frac{3}{4}\cdot$H mm)

$$\theta_{\mathrm{Offset}} = \frac{1}{n}\sum_{i=1}^{n}\theta_i \qquad \theta_{\mathrm{RMS}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}{\theta_i}^2} = \sqrt{\frac{{\theta_1}^2 + {\theta_2}^2 + \cdots + {\theta_N}^2}{N}}$$



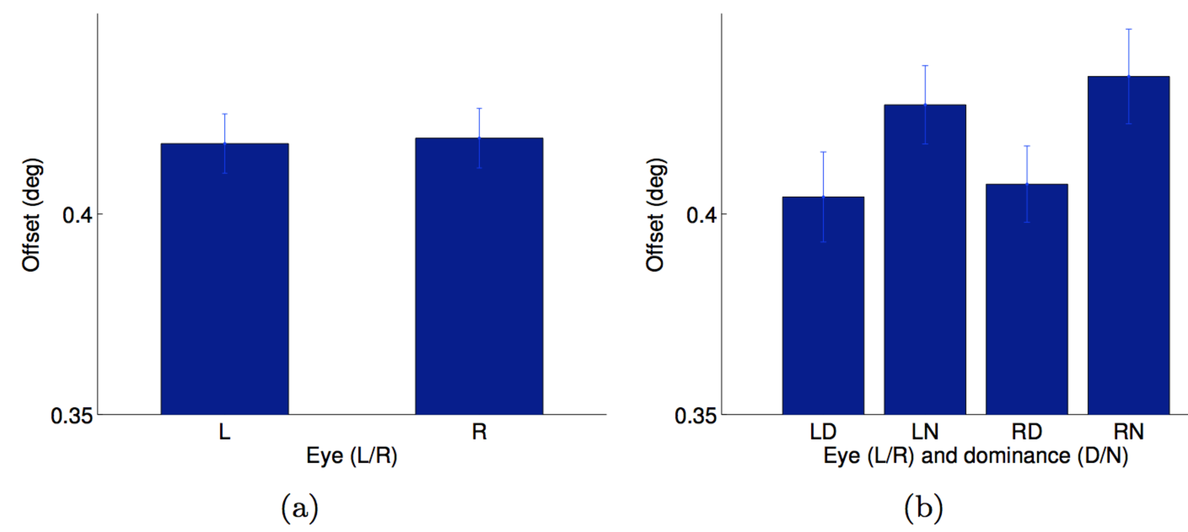
RESULTS

Accuracy is better with experienced operators



Operators 2-6 had extensive experience with this particular eye-tracker. Operator 1 had only recorded with head-mounted eye-trackers.

Dominant eye (Miles test) gives better accuracy

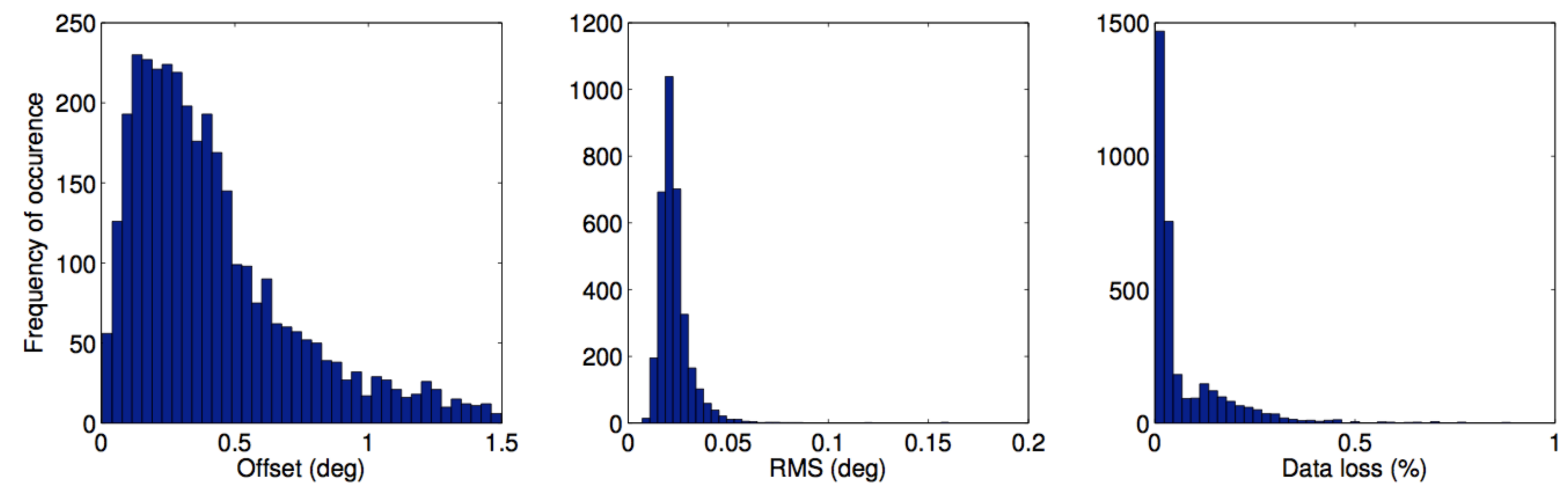


No difference between L and R eye.

Left dominant (LD) and right dominant (RD) eye give better accuracy than non-dominant eyes (LN and RN).

RESULTS

Histograms over all data



Data analysis using a linear mixed-effects model: the lme4 package of R.

Accuracy (offset) is predicted by:

Predictor	min95	mean95	max95	p-value
Participant-controlled	-0.1192	-0.06668	-0.0072	0.0302
Operator-controlled	-0.07222	-0.01998	0.03953	0.4958
Off-center target	-0.00098	0.00000	0.00005	0.5402
Target placed low	-0.0001	-0.00005	0.00000	0.0022
measurementNo2	0.2454	0.2747	0.3045	0.0001
EyeColorBrownish	-0.06158	-0.00443	0.06161	0.8762
EyeColorOther	-0.1189	0.2259	0.8560	0.2520
VisualAidsGlasses	0.03837	0.1619	0.3061	0.0064
VisualAidsLenses	0.1613	0.2458	0.3362	0.0001
EyeLashesForward	0.01188	0.08243	0.1661	0.0248
EyeLashesDown	0.04827	0.1828	0.3482	0.0052
Mascara	0.00034	0.06581	0.1448	0.0570
Eye Right	-0.01801	0.1299	0.04165	0.3790
DominantEye Right	-0.02526	0.03098	0.09206	0.2830
EyeR:DominantEyeR	-0.07155	-0.03789	-0.00102	0.0400
EyePhysiologyMedium	-0.2306	-0.1059	0.08341	0.2292
EyePhysiologyOpen	-0.2547	-0.1462	0.0079	0.0680

Accuracy:

Participant-controlled calibration best
Higher position on monitor better
Glasses make accuracy worse
Open eye physiology better
Better accuracy on dominant eye
Accuracy decreases over time

Precision (RMS) is predicted by:

Predictor	min95	mean95	max95	p-value
Participant-controlled	-0.00352	-0.00200	-0.00034	0.0160
Operator-controlled	-0.00233	-0.00090	0.00061	0.2444
Off-center target	0.00000	0.00000	0.00000	0.0001
Target placed low	0.00001	0.00001	0.00001	0.0001
measurementNo2	0.00059	0.00088	0.00116	0.0001
EyeColorBrownish	-0.00530	-0.00391	-0.00252	0.0001
EyeColorQuite other	-0.01265	-0.00772	-0.00097	0.0268
VisualAidsGlasses	0.00709	0.01041	0.01421	0.0001
VisualAidsLenses	-0.00286	-0.00142	0.00001	0.0602
EyeLashesForward	-0.00328	-0.00172	-0.00007	0.0394
EyeLashesDown	-0.00313	-0.00035	0.00261	0.8178
Mascara Residues	-0.00135	0.00131	0.00436	0.3572
Mascara Yes	-0.00116	0.00040	0.00218	0.6330
Eye Right	0.00114	0.00159	0.00203	0.0001
DominantEye Right	-0.00044	0.00098	0.00247	0.1674
EyeR:DominantEyeR	-0.00016	0.00039	0.00094	0.1692
EyePhysiologyMedium	-0.00971	-0.00603	-0.00162	0.0084
EyePhysiologyOpen	-0.00901	-0.00534	-0.00126	0.0134

Precision:

Participant-controlled calibration best
Higher position on monitor better
Blue eyes are worse than brown
Glasses make precision worse
Open eye physiology is better
Precision decreases over time

Amount of data loss is predicted by

Predictor	min95	mean95	max95	p-value
Operator-controlled	-0.01641	0.00055	0.01495	0.9420
System-automatic	-0.03424	-0.01335	0.00484	0.1490
Off-center target	-0.01163	-0.01021	-0.00891	0.0001
Target placed low	-0.00288	-0.00211	-0.00130	0.0001
ValidationNo2	-0.01487	-0.01012	-0.00546	0.0001
VisualAidsGlasses	0.00128	0.02323	0.03943	0.0416
VisualAidsNone	0.00509	0.01761	0.02817	0.0084
EyeLashesForward	-0.03211	-0.01099	0.00548	0.2156
EyeLashesDown	-0.02165	0.00730	0.02955	0.5834
EyeColorBrownish	-0.02104	-0.00306	0.01148	0.7100
EyeColorOther	-0.34447	-0.11866	0.00422	0.0582
Mascara Residues	-0.05155	-0.01597	0.01105	0.2794
Mascara Yes	-0.03460	-0.01330	0.00287	0.1206
Eye Right	0.00063	0.00689	0.01243	0.0296
DominantEye Right	-0.00451	0.00884	0.02010	0.1864
EyePhysiologyMedium	-0.06264	0.00194	0.03843	0.9310
EyePhysiologyOpen	-0.01082	0.02937	0.05129	0.1228
EyeR:DominantEyeR	-0.00993	-0.00121	0.00716	0.7792

Data loss:

Higher position on monitor better
Glasses make data loss worse
Lenses make data loss worse
Data loss increases over time