Real-life *in situ* measurement of blinking using a wearable device: establishing a gold standard for spontaneous blinking

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Background

- Blinking essential to ocular surface homeostasis [1]
- Blink assessment hampered in part by the lack of a gold standard measurement
- Blink repeatability measurement not been reported
- Spontaneous blink parameters vary between tasks [1]
- Measurements often occur in lab settings not representative of real-life situations

AIM:

- To measure blinking *in situ* in a real-life setting, during various reading and non-reading tasks
- **Secondary aim:** To examine day to day repeatability of blinking

Methods

Study design: randomised, cross-over, open label

During the study:

- Eight randomly assigned tasks (15min each) completed over 2 visits: A) conversation; reading from B) printed text, C) laptop screen, D) smart TV at 6m, E) smartphone, F) smartphone at 50% brightness, G) smartphone (more complex text); and H) walking indoors
- Task E completed twice, before other tasks, two days apart, to determine day-to-day repeatability

Participants: Twenty-four healthy adults (28.6 ±6.3 years; 8M:16F); university students

Exclusion criteria: Ametropia, contact lens or spectacle wear, abnormal binocular vision, ocular or systemic condition, or use of medications likely to impact blinking

Measurements:

- Blinking assessed from videos recorded with wearable eye tracking headset (Pupil Labs, GmbH Berlin, Germany) connected to a laptop/smartphone (Figures 1)
- Pupil Labs software algorithm :
  - assigns a value to detected pupil in each video frame referred to as pupil confidence, ranging from 0 (no confidence) to 1 (perfect confidence) [2]
  - identifies blink activity in the recording based on pupil detection [2]
- Blink starts when pupil confidence drops below onset threshold (0.5s) within the time window length (0.2s) and ends when pupil confidence recovers above the offset threshold (0.5s) (Figure 2) [2]
- Interblink interval time between the end of a blink and the start of another blink manually estimated from blink onset and offset timestamp
- Blink data with more than 60% of pupil confidence values above 0.6 were included in the final analysis
- Ocular symptoms measured with Instant Ocular Symptoms Survey (IOSS) [3] before and after each task

Statistical Analysis

- Blink rate and interblink interval compared between tasks using repeated measures ANOVA, post hoc comparisons with Bonferroni correction
- Ocular symptoms compared pre- and post-task using paired t-test
- Associations between blinking and change in symptoms examined using Pearson correlation with Bonferroni adjustment
- Repeatability assessed using Bland & Altman method (Coefficient of Repeatability, CoR)

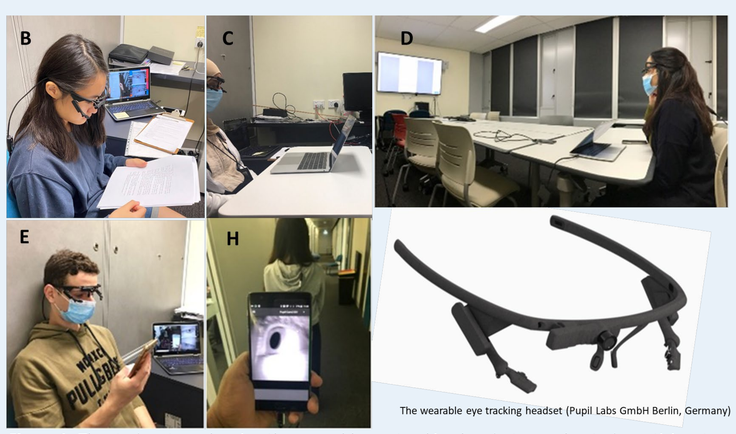

Figure 1. *The study set-up showing the wearable eye tracking headset worn by study participants during various tasks and connected to a laptop during reading from B) printed text, C) Laptop, D) smart TV at 6 meters, E) smartphone (representing all smartphone tasks E – G) and connected to an android phone during H) walking*

Figure 2. Blink detection timeline showing onset and offset thresholds (yellow lines), pupil confidence variations (green lines), detected blinks and interblink interval (binary presentation i.e., high pink line and low pink line plot respectively)

Results

Blink rate

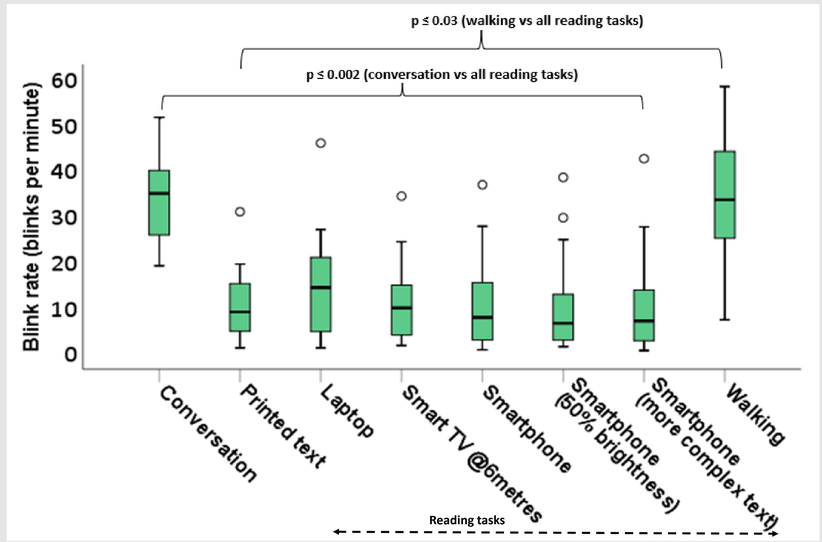

Figure 3. Blink rate by tasks. All tasks involved reading except conversation and walking. Dots represent mild outliers. There was no extreme outliers.

- Blink rate was reduced with all reading tasks compared to conversation and walking (p≤0.03)
- No differences in blink rate between conversation and walking, nor between any of the reading tasks

Interblink interval

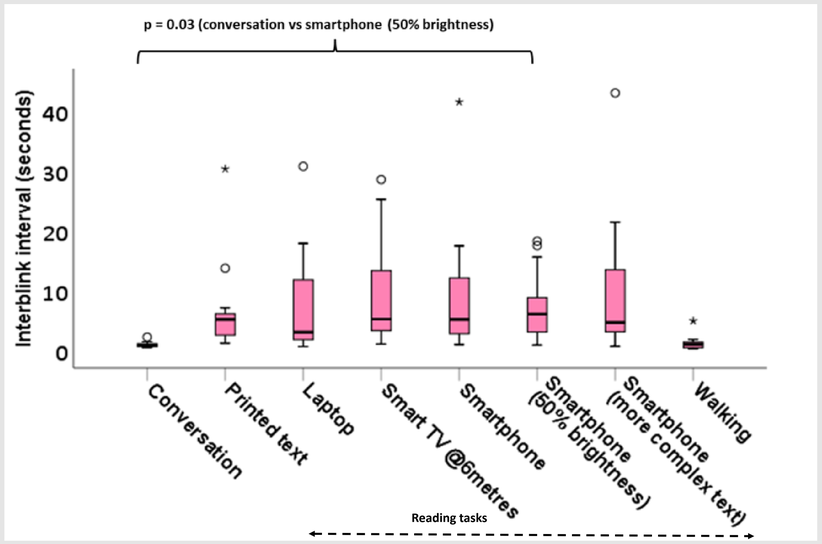

Figure 4. Interblink interval by tasks. All tasks involved reading except conversation and walking. Dots/stars represent mild/extreme outliers.

- Interblink interval was higher in magnitude during reading tasks compared to conversation and walking indoors (p>0.05)
- Significant difference found only between reading on smartphone (50% brightness) and conversation (p=0.03)

Ocular symptoms before and after tasks

Task	Conversation	Reading						Walking
		Printed text	Laptop	Smart TV @6metres	Smartphone	Smartphone (50% brightness)	Smartphone (more complex text)	
Ocular symptoms score								
Before task (mean±SD)	2.5±2.2	2.5±2.3	2.7±2.0	2.0±1.6	2.0±2.2	2.6±2.1	2.6±2.0	2.2±2.0
After task (mean±SD)	2.1±1.9	2.4±2.2	3.1±2.0	3.9±2.2	2.5±2.4	3.4±2.2	3.5±2.1	1.8±1.6
p-value	0.17	0.49	0.11	**≤0.001**	0.16	**≤0.001**	**≤0.001**	0.15

- Ocular symptoms were worse after reading from a smartphone at reduced brightness (p≤0.001), more complex text (p≤0.001) and from a distant TV screen at 6m (p≤0.001)
- No significant associations between blink rate, interblink interval and change in symptoms (p>0.05)

Repeatability of blink measurements

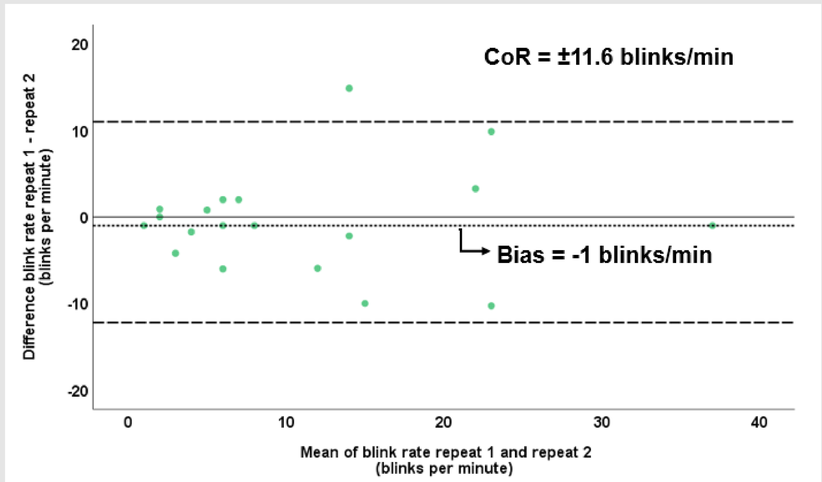

Figure 5. Differences between blink rate/min repeat 1 and 2 plotted against their mean, while reading from a smartphone. The dotted lines represent the bias which was not different to zero (p= 0.72). The dashed lines represent the limits of agreement of +11.0 to -12.2 blinks/min.

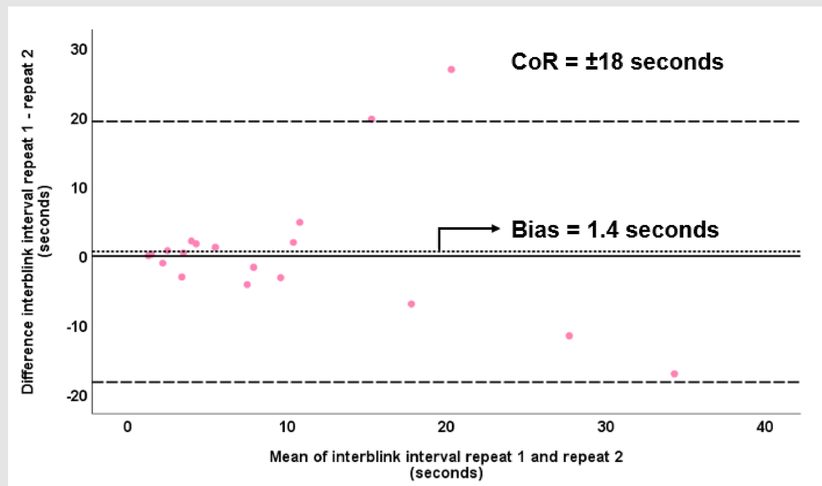

Figure 6. Differences between interblink interval in seconds repeat 1 and 2 plotted against their mean while reading from a smartphone. The dotted lines represent the bias which was not different to zero (p=0.53). The dashed lines represent the limits of agreement of +19.7 to -16.9 seconds.

Discussion

- Blink rate was reduced during reading compared to conversation and walking and the magnitude of the difference was similar to previous reports [1].
- Reading task complexity, working distance or device used, did not affect blink rate in contrast to other studies,[4,5] this may be due to blink measurement difference or task duration.
- Increase in blink rate during more difficult task has been linked to factors such as time on task, a measure of fatigue, and blink observation methods[6].
- Screen brightness did not affect blink rate; this aligns with Lowes's study [7] and may be due to good background illuminance [8].
- Interblink interval, sparsely reported has been described as dynamic and unconsciously adjusted i.e., shorter during alertness [9], e.g., conversation.
- Interestingly, ocular comfort was reduced in the more complex reading task and with reduced screen brightness but was not associated with blinking.
- Previous studies have reported worsened ocular symptom during similar tasks as an adverse effect of reduced blink rate and poor blink amplitude [9]. This warrants further investigation with the eye tracking headset.
- The CoR suggests higher variability with repeated measures of interblink interval than the blink rate.
- Pupil obscuration unrelated to blinks can occur due to extreme gaze angles or by eyelashes [2] which may record as interblink interval.
- The first study to report the day-to-day repeatability of spontaneous blinking parameters. Blink rate appears stable day to day.

Conclusion

- Blink rate is repeatable day to day and can reliably be measured *in situ* using the wearable eye tracking headset.
- In a real-life setting, blink rate was reduced during reading compared to conversation or walking, irrespective of reading task complexity, screen brightness, working distance or device used.

References

1.Doughty. Optom Vis Sci, 2001. 78(10): p. 712-725.
2. PupilLabs. https://docs.pupil-labs.com/#blink-detection.
3.Boga et al. Ocul Surf, 2019. 17(4): p. 763-770.
4. Rosenfield et al. Computers in Human Behavior, 2015. 51: p. 403-406.
5. Cardona et al. Curr Eye Res, 2011. 36(3): p. 190-197.
6. Stern et al. Human Factors, 1994. 36(2): p. 285-297.
7. Lowe et al. AAO abstract, 2017. Program Number: 175104.
8. Doughty. Eye & Contact lens, 2013. 39(2): p. 138-146.
9. Ranti et al. Scientific Reports, 2020. 10(1): p. 1-10.
10. Jaiswal et al. Clin Exp Optom, 2019. 102(5): p. 463-477..

Disclosures: None

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