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ORIGINAL ARTICLE

Effect of distance vision and refractive error on the spontaneous eye blink activity in human subjects in primary eye gaze

Michael J. Doughty*

Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 OBA, United Kingdom

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Eye blinking;
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Abstract
Purpose: To evaluate whether visual target character and visibility affects spontaneous eye blink rate (SEBR) in primary eye gaze and silence.
Methods: Video recordings were made of young healthy adults who were either emmetropic ($n = 32$) or who wore spectacles for refractive error (range −4.75 D and +4.50 D ($n = 31$). Emmetropes had 5 min recordings made whilst seated and looking towards a distant whiteboard. For spectacle wearers, recordings were made whilst looking towards the whiteboard with a 35 mm sized cross, and repeated after spectacle removal. The average number of eye blinks over 5 min was assessed, and its intra-subject variability as the coefficient of variation (COV).
Results: Over 5 min without a distance target, an average SEBR of 10.4 blinks/min was observed in emmetropes with a of COV = 38.1%, and a significant increase in SEBR over the 5th minute to 13.6 blinks/min. Hyperopes being asked to look towards a distant target showed the essentially same blinking rate of 11.1/min with or without spectacle wear with the intra-subject variability (COV) being 21.3%. Myopic subjects showed a slightly higher SEBR if looking towards a target without their spectacles (12.4 vs. 11.0 blinks/min), with the COV being 18.8%.
Conclusions: The studies indicate that some form of visual target could be useful to promote constancy of spontaneous eye blink activity over time, but that a distance visual target (when provided) does not need to be seen clearly.

* Correspondence to: Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 OBA, United Kingdom.
E-mail address: m.doughty@gcal.ac.uk

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PALABRAS CLAVE
Parpadeo del ojo;
Humano;
Visión;
Visión borrosa;
Error refractivo

Efecto de la visión de lejos y el error refractivo sobre la actividad del parpadeo espontáneo del ojo en sujetos humanos en posición primaria de la mirada

Resumen
Objetivo: Evaluar si el tipo y visibilidad del objetivo visual afecta a la tasa de parpadeo espontáneo del ojo (SEBR) en posición primaria de la mirada y en silencio.
Métodos: Se realizaron grabaciones de vídeo de jóvenes adultos sanos, emétropes (n = 32), o que utilizaban gafas para el error refractivo (rango: −4,75 D y +4,5 D (n = 31). Se realizaron grabaciones de 5 min a los emétropes mientras permanecían sentados y miraban a una pizarra de lejos. Para los sujetos que utilizaban gafas, se realizaron grabaciones mientras miraban a la pizarra con una cruz de 35 mm de tamaño, repitiéndose dichas grabaciones tras retirarles las gafas. Se evaluó el número medio de parpadeos durante 5 minutos y su variabilidad intra-sujeto como coeficiente de variación (COV).
Resultados: Durante un periodo de 5 minutos sin objetivo visual, se observó una SEBR media de 10,4 parpadeos/min en emétropes con un COV = 38,1%, así como un incremento significativo de SEBR a lo largo del quinto minuto a 13,6 parpadeos/min. En los hipermétropes a quienes se solicitó mirar a un objetivo de lejos se observó prácticamente la misma tasa de parpadeo de 11,1/min con o sin utilización de gafas, con una variabilidad intra-sujeto (COV) del 21,3%. Los sujetos miopes reflejaron una SEBR ligeramente superior cuando miraban al objetivo sin utilizar gafas (12,4 vs. 11 parpadeos/min), con un COV del 18,8%.
Conclusiones: Los estudios indican que cierta forma de objetivo visual podría resultar útil para promover la constancia de la actividad de parpadeo espontáneo del ojo en el tiempo, pero que un objetivo visual lejano (de existir) no precisa ser visto con claridad.

Introduction

From studies conducted over many years, spontaneous or endogenous eye blink activity can be broadly considered as that which occurs without any obvious external or internal stimulation and is an unconscious process.[1] Spontaneous eye blink activity has been categorized as being 'blinking of uncertain origin' in that it occurs 'without the intervention of any obvious stimulus to touch, dazzle or menace'.[2] Overall, such activity is considered to be distinct from when a deliberate stimulus is presented to the eye or other parts of the body (e.g. aural, tactile or even electrical stimuli) and that then result in some form of reflexive eye blink activity.[3]

If this so-called spontaneous eye blink activity (SEBR) is assessed for subjects adopting a primary eye gaze without talking (i.e. essentially in silence), then analyses of studies published over many years indicates that it has reasonably predictable average values; the overall mean SEBR was estimated to be around 14.5 blinks/min and with a statistically-definable range of average values from 8.5 to 21 eye blinks/min.[1] This option to assess SEBR has been widely used, also referred to as a 'look straight ahead' experimental paradigm (Table 1).[4]

With the primary eye gaze experimental paradigm for assessing SEBR an individual would be looking towards something ahead of them. It is perhaps surprising that very little attention seems to have been given to what the subjects might be given to look at during such assessments. From one perspective, it might generally be argued that this simply does not matter because detailed studies on SEBR have been undertaken for nearly 100 years,[5] with no notable comments raised on this issue. However, the variability in average SEBR values reported over many years could have arisen because of there being either differences in what the subjects were actually looking at whilst SEBR was being assessed (in silence) and/or how well subjects might have been able to see clearly at distance when being asked to look towards some type of visual 'target'. For example, in one study the

Table 1 Summary of eye blink (SEBR) data in primary gaze and in silence.

Group	Refractive error (DS)	Visual target	SEBR over 5 min (blinks/min)	COV on SEBR (%)
1	0	Small whiteboard without cross	10.1 ± 4.0	35.8
2	0	Large whiteboard without cross	10.6 ± 3.3	39.5
1 and 2 together	0	Small or large whiteboard without cross	10.4 ± 3.5	38.1
3	+2.70 ± 0.95	Large whiteboard with 35 mm high cross	11.1 ± 1.6	21.3
4	−2.95 ± 0.97	Large whiteboard with 35 mm high cross	12.4 ± 1.9	18.8

subjects were comfortably seated and looking at the centre of a screen 2 m distant while being videographed over 5 min.[6] Similarly, in another study, subjects were asked to sit silently in front of a blank neutral wall during SEBR recording over several minutes but now with electrode-based methods to detect eye blinks.[7]

In another study specifically designed to assess the constancy of eye blink activity over time, subjects were seated in a high-backed chair and asked to look towards a high contrast black cross (35 mm in size) on a distant wall.[8] The same paradigm was used in later studies where subjects with 'mild-to-moderate' refractive errors were asked to direct their gaze towards the same distant target after having removed their spectacles.[9] In the first study, the range of SEBR values over 5 min was from 3.8 to 17.4/blinks/min,[8] and while in the second study the range of SEBR values was not given, a similar variability was evident in the inter-blink interval values.[9] While some slight fluctuations in the averaged minute-by-minute values were evident in both studies, no time-related changes in SEBR values over 5 min were detectable even with the study sample being as large as 61 subjects.[9] Nonetheless, the ranges of SEBR values could have been dependent on the variable of refractive error present. No analyses were reported with it simply being stated that the subjects indicated that they were able to see the target satisfactorily but that it was not considered important that the subjects were able to see it clearly.[9]

The broad objective of the present studies was to examine whether or not a distance visual target was needed and/or whether it needed to be clearly seen to obtain stable measurements of eye blink activity for subjects in primary eye gaze and while not talking. The actual minute-by-minute variability in the SEBR data was assessed by specifically considering the coefficient of variation (COV) of the averaged values.

Materials and methods

Subjects

After approval of the protocols from the university ethics committee, the experiments were explained to the subjects and consent obtained. All procedures involving these human subjects were in accordance with the tenants of Helsinki. The subject recruitment, from undergraduate or graduate students in Vision Sciences, was essentially based on individuals being emmetropic or being spectacle wearers who had no known ocular condition other than refractive error. Subjects were simply asked if they could be available to sit in a clinic room for a few minutes while a video recording was made of them. Their selection was based on their being in good health with no known neurological disorders, neither taking any medications that might substantially affect eyeblinking, pupil activity or oculomotor functions. Subjects were also checked to be nominally free of any clinically significant ocular surface disease based on subject reporting of any known ocular disease, e.g. current allergic conjunctivitis, specific and notable ocular irritation associated with systemic medication use, recent infections of the eye or recent cold/cough, etc. The subjects were also specifically asked if they had any eye complaints (such as gritty, scratchy, sore or burning eyes) and whether they had itchy or swollen eyelids. In addition, a cursory examination of the external eye was made to see if there were any obvious abnormalities of the palpebral aperture, eyelid margins, blepharitis, etc. None of the subjects were current or regular contact lens wearers.

The sample size, including the subgroups, was considered large enough to detect a difference equal to the observed SD on SEBR values in previous studies (of 3 eye blinks/min) with at least an 80% probability. Overall, 32 emmetropes were evaluated for one part the study (groups 1 and 2), while 14 hyperopes (group 3) and 15 myopes (group 4) were assessed in the second part of the study.

Eye blink recording

The subjects were adapted to the examination room environment over several minutes being asked to make themselves comfortable while seated in an office chair with head back rest, and were verbally (but quietly) encouraged to relax and wait for instructions. The same essential set up was as described previously.[8,9] The ambient temperature (range 18–21 °C) and humidity (31–40%) were controlled by a central forced-air circulatory system, but the fan was usually off or only on low speed so as minimize any perceptible air currents, drafts and background noise. The observation room was not sound-proofed, but it was usually possible to maintain reasonable quiet throughout the recordings. The lighting (about 350–400 lux) was provided by a series of ceiling mounted fluorescent tubes. In initial assessments made for this study, a small white board (1 m × 0.5 m) was on the wall towards which the subjects were asked to direct their gaze during 5 min video recording, but a more substantial wall coverage (2 m × 1 m) was adopted for most of studies as indicated. The luminance at the white board was between c. 30 and 45 cd/m^2.

A camera was tripod-mounted just in front of the subjects but off at an angle so as not to be within their central field of view. The subjects were aware that the camera was focussed on their face but were simply asked to direct their gaze towards the whiteboard 2 m distant. They were asked sit quietly and to maintain this binocular gaze while staying relaxed until told the recording was over. The examiner was positioned to one side of the subjects out of their field of vision. While the examiner kept track of time, the subjects were not advised as to how long the recordings might take nor were they given any cues as to how much longer the recording might take etc. The video file was then saved under the subject number code for future analysis. All recordings were made during the course of a normal working day between 10.00 and 17.00 h.

Experimental protocols

The first and second sets of emmetropic subjects (groups 1 and 2) had a 5 min recording while they sat with their gaze directed towards the whiteboard, with the only difference between the groups being the size (area) of the whiteboard which was small or large. Group 3 subjects were all spectacle-wearing hyperopes who also had a single 5 min recording made whilst looking towards the large

whiteboard on which was affixed an A4 sized piece of white paper on which was printed a 35 mm high cross, as previously illustrated.[9] These subjects were then given a short rest (as the examiner saved the video files, which usually took 2–3 min), and then the recording repeated without the spectacles. During both recordings, the hyperopic subjects simply sat in the high-backed chair directing their gaze towards the 35 mm high distant target. Spurious reasons were provided as to why a second recording was requested, such as the examiner might get a better view if they were not wearing their spectacles. Group 4 subjects were spectacle-wearing myopes, who also had two recordings made (with and without their spectacles) as for the hyperopes.

The video recordings were assessed using the software included in the camera operation system. The procedure followed was to simply replay the recording and manually count the number of blinks in each successive minute, replaying sections of the recording if there was any uncertainty. Only obvious eyelid movements were noted, i.e. those that produced at least one half coverage extending over part of the pupil or completely occluding the pupil. Any eyelid twitches or tremors were ignored.

Statistical analyses

All data were entered into spreadsheets in Systat v. 11 (Systat, Evanston, IL) to generate global statistics and graphical outputs. For all data sets, the mean of the average SEBR values was calculated, the SD and the coefficient of variation [COV = (mean SEBR/SD) * 100]. The normality of all data sets was checked using the default Shapiro–Wilk statistic as incorporated in Systat, with a value of $p < 0.05$ being considered non-normal. Comparisons between data sets were generally made using a paired *t*-test (for intra-session comparisons of the same subjects) so that any time-related (minute-by-minute) differences could be detected. A few data sets (see results) were also compared using a non-parametric Friedman rank order test. In addition, over the 5 min period, a step-wise linear regression model was applied to the averaged data. In all comparisons, the level of statistical significance was set at $p = 0.05$.

Results

Overall characteristics of the spontaneous eye blink activity and its assessment

The subjects across all 4 groups were aged between 19 and 30 years (average ± SD, 22 ± 3 years), and there were no statistical differences between the groups. Their self-reported refractive error ranged from −4.75 DS to +4.50 D spherical equivalents, with no subject reporting major cylindrical errors. All subjects displayed what was considered to be normal spontaneous eye blink activity, which showed the following features. When asked to relax and direct their gaze towards the distant whiteboard, all subjects showed periodic but transient eyelid closure (to at least cover the pupil) and re-opening events of short duration (≤200 ms), with no obvious episodes of extended lid closure over a 5 min recording period. In all of the assessments, the subjects appeared to have no difficulty with simply sitting quietly for a few minutes and maintain primary eye gaze, and in no case were there obvious changes in head posture or saccadic eye movements during the short recordings.

Spontaneous eye blink rate (SEBR) assessments for emmetropes without a defined distant target

A total of 32 subjects were assessed and reliance was placed on the subjects to indicate that they did not have any spectacle needs and that they had no visual complaints. The overall results are shown in Fig. 1.

The group 1 set of 12 subjects, who were asked to direct their gaze towards the small whiteboard while their eye blinking was assessed, were aged between 19 and 32 y (average 23.7 ± 3.8 y), and were observed to have an averaged SEBR (over 5 min) of 10.1 ± 4.0 blinks/in (mean ± SD). The overall minute-by-minute intra-subject variation in SEBR (as the COV) was 35.8%. However, as shown in Fig. 1A, this averaged value (over 5 min) came from some slightly lower and some slightly higher SEBR values. For example, over the 1st minute of recording, the averaged SEBR was 9.2 blinks/min, while in the 5th minute it was 12.2 blinks/min; these 2 sets of averaged values were however not statistically different ($p = 0.527$, Friedman ANOVA) mainly because of the rather substantial inter- and intra-subject variability in SEBR values at these two time points. Similarly, the averaged SEBR values in the 2nd, 3rd and 4th minute was not detectably different from those in the 1st minute ($p \geq 0.378$). Notwithstanding, with the averaged SEBR values appearing to get progressively greater with time (Fig. 1A), an overall time-related analysis of SEBR (by regression) indicated a just detectable increase ($p = 0.046$).

The 20 group 2 subjects were also emmetropes had an average age of 21.2 ± 1.7 y (range 18–25 y) and were asked to relax and direct their gaze towards a large whiteboard. Over 5 min, their averaged SEBR was 10.6 ± 3.3 blinks/min, with the overall intra-subject variability (as COV) being 39.5%. Overall, therefore, these results were no different from those in group 1. Analysis of the SEBR over time indicated a progressive increase (Fig. 1B) that was now measurably different. So, for example, the averaged SEBR in the 1st minute was 9.0 blinks/min, was essentially unchanged for the 2nd and 3rd minute (with averages of 9.6 and 9.3 blinks/min) but higher values were observed over the 4th and 5th minutes (of 11.0 and 14.4 blinks/min respectively). The change in the 4th minute (compared to the 1st minute) was not statistically significant ($p = 0.74$, Freidman), but the increase over the 5th minute was significant ($p = 0.039$). The graph (Fig. 1B) indicates this overall lack of constancy in the SEBR over time, although a time-related regression analysis just failed to realize statistical significance ($p = 0.057$).

With the results from group 1 and group 2 being similar, these were combined as an assessment of SEBR for emmetropes who were essentially being asked to look at a blank wall while their eye blink activity was being assessed. There were thus 32 subjects with an average age of 22.1 ± 2.9 y. Their averaged SEBR over 5 min was now 10.4 ± 3.5 blinks/min, with the overall intra-subject variability being 38.1%. The pooled data exhibited a very similar time-related profile to the separate data sets (compare Fig. 1C to A and B) with the averaged SEBR over

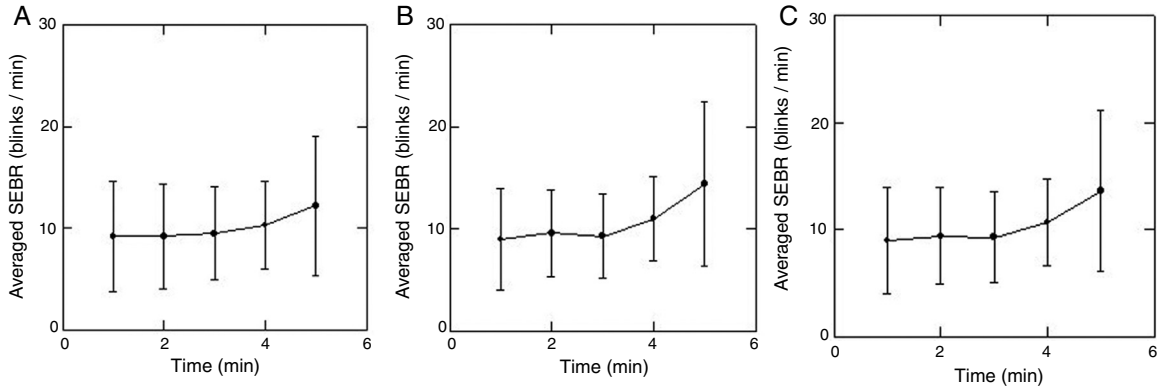

Figure 1 Outcome of spontaneous eye blink rate (SEBR) assessments from video recording of emmetropic subjects looking (a) towards a small blank whiteboard or (b) towards a large blank whiteboard and (c) both sets of data combined. The plots show minute by minute averaged values ± SD.

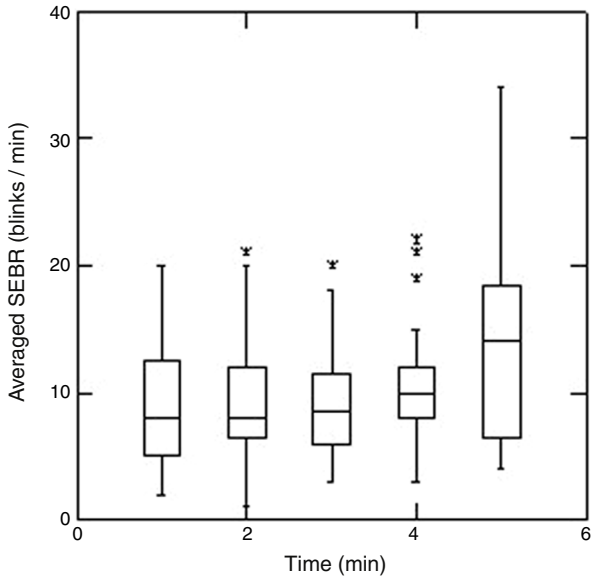

Figure 2 Box plot to illustrate increasing variability in spontaneous eye blink rate (SEBR) over time for emmetropic subjects directing their gaze towards a distant blank whiteboard. Asterisks indicate outliers (see text).

the 5th minute being noticeably higher at 13.6 blinks/min ($p = 0.041$ compared to averaged 1st minute values of 9.0 blinks/min). Notwithstanding, an overall time-related analysis (by regression) just failed to detect a significant increase ($p = 0.054$), again because of the obvious increase in the variability at later times (as seen with the large SD values in Fig. 1C). This aspect of the SEBR for group 1 and group 2 subjects was therefore analyzed in more detail (Fig. 2).

The box plot is presented to illustrate a trend in the data over the initial 4 min and the rather abrupt change over the 5th minute. Over minutes 1–4, the overall inter-subject variability in SEBR decreased slightly, as evidenced from the progressively smaller ±25% inter-quartile intervals (IQIs). However, while only one outlier (shown as an asterisk) was evident for the 2nd and 3rd minutes, 3 of them were identified in the 4th minute. Over the 5th minute, the IQI was substantially larger as was the ±1.5 SD range, but no actual outliers were detected.

Spontaneous eye blink rate (SEBR) assessments for hyperopes with and without wearing their spectacles while looking at a distant target

Based on the information provided by the subjects, their spectacle prescriptions provided adequate visual correction for distance vision, and all had been wearing the same glasses for at least 1 y. The reported refractive error averaged +2.70 ± 0.95 DS (range +1.50 to +4.50 DS). These 14 hyperopes had an average age of 21.6 ± 2.5 y (range 18–27 y). While observed as they directed their gaze to the distant target on the large whiteboard, their averaged SEBR was 11.1 ± 1.6 blinks/min. On a minute-by-minute basis (Fig. 3A), there was no obvious trend in the averaged SEBR values ($p = 0.745$) and each set of SEBR values (minute 1, minute 2, etc.) was statistically identical ($p \geq 0.132$, Friedman). Overall, the minute-by-minute variability in SEBR (as the COV) was just 20.5%.

When the video recordings were repeated essentially immediately after these hyperopes were asked to remove their spectacles, the SEBR values were slightly higher (e.g. averaging 11.9 ± 1.7 blinks/min over 5 min), but there was no detectable time-related change ($p = 0.254$, Fig. 3B) with the sets of SEBR in each minute being the same ($p \geq 0.394$). The overall time-related intra-subject variability in SEBR (as the COV) was 21.3%. As assessed with a simple liner regression model, there was no predictable differences in the averaged SEBR over the 5 min in relation to the reported refractive error ($p = 0.472$).

Spontaneous eye blink rate (SEBR) assessments for myopes with and without wearing their spectacles while looking at a distant target

As with the hyperopes, reliance was placed on the subjects to indicate the adequacy of their spectacle correction and their reported refractive error averaged −2.95 ± 0.97 D (range −4.75 to −1.25 DS). These 15 myopes had an average age of 22.1 ± 2.3 y (range 19–27−y). When these

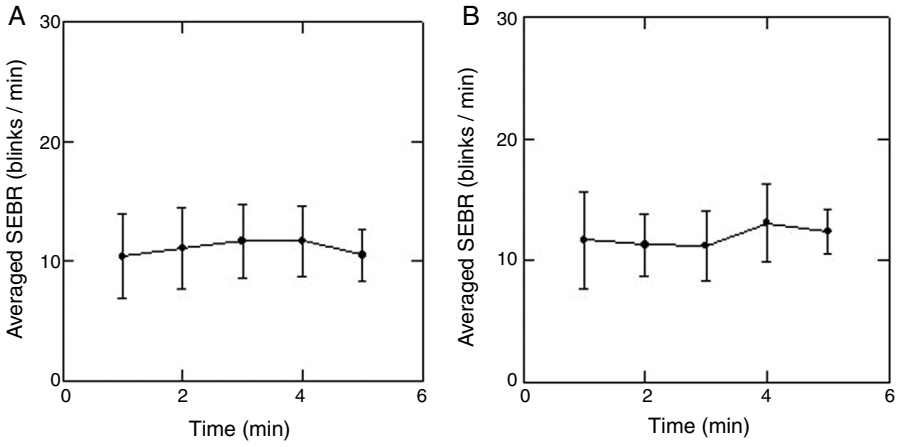

Figure 3 Outcome of spontaneous eye blink rate (SEBR) assessments from video recording of 14 hyperopic subjects looking at a distant target on a large whiteboard (a) whilst wearing their spectacles or (b) without their spectacles. Error bars indicate SD.

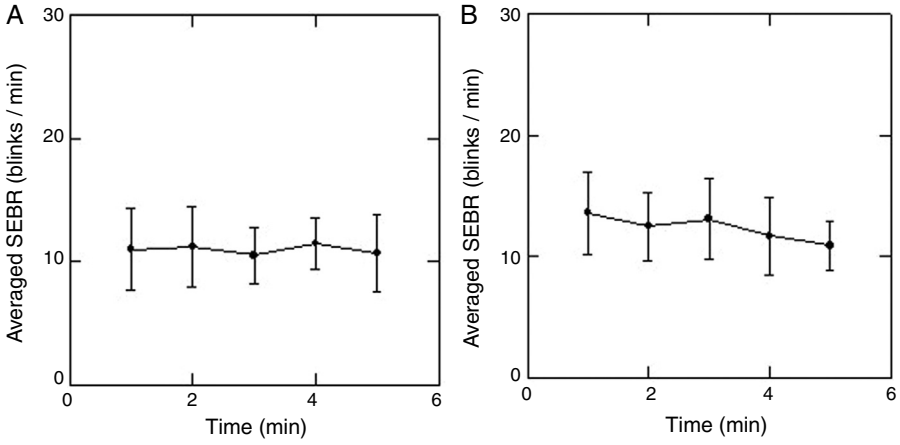

Figure 4 Outcome of spontaneous eye blink rate (SEBR) assessments from video recording of 15 low myope subjects looking at a distant target on a large whiteboard (a) whilst wearing their spectacles or (b) without their spectacles. Error bars indicate SD.

myopes were asked to direct their gaze towards the distant black cross target while wearing their spectacles, their averaged SEBR over the 5 min video recording was 11.0 ± 2.2 blinks/min. As shown in Fig. 4A, there was no obvious time-related change in SEBR seen in these myopes ($p = 0.848$) and the overall minute-by-minute intra-subject variability was just 15.9%. There were no detectable differences in each set of SEBR values observed in each minute ($p \geq 0.576$).

A slight change in the time-related SEBR profile was observed when these myopes were reassessed immediately after removing their spectacle (Fig. 4B) even though the overall difference just failed to be statistically significant ($p = 0.056$). The overall change was a trend towards the averaged SEBR being marginally higher over 5 min (at 12.4 ± 1.9 blinks/min, compared to 11.0 blinks/min while wearing spectacles) with a intra-subject variability (COV) of 18.8%, but this was obviously the result of initially higher values that then declined with time ($p = 0.034$). There seemed to be a progressive adjustment, by the myopes without their spectacles, when looking towards a distant target that would have been quite substantially out of focus for some of them (as verified by questions asked). So, it can be noted that over the 5th minute of observation the averaged SEBR when they were wearing their spectacle was 10.7 ± 3.1 blinks/min. This same result was obtained over the 5th minute after spectacles were removed (averaged SEBR of 10.9 ± 2.0 blinks/min; p NS). The slightly higher overall SEBR over the 5 min (i.e. of 12.4 blinks/min) was therefore due to higher blink rates being observed over the 1st minute after spectacle removal (averaged SEBR of 13.6 ± 3.4 blinks/min) and also over the 3rd minute (averaged SEBR of 13.3 ± 3.3 blinks/min). The blink activity over the 4th minute was lower than in the 1st minute (but not significantly different, $p = 0.105$, Friedman), but the averaged SEBR over the 5th minute was statistically lower than the 1st minute ($p = 0.005$). Overall, there was no detectable inter-relationship between the averaged SEBR over 5 min and the subject's spectacle prescription ($p = 0.110$).

Discussion

The present studies were designed to evaluate whether or not the spontaneous eye blink rate (SEBR), under as reasonably controlled experimental conditions as possible, was

constant or changed. The main experimental variables being whether or not the presence of visual target (at distance) had any influence SEBR and whether the subjects needed to be able to clearly see a distant target. The blank white wall paradigm was selected as providing no obvious stimulus for complex visual processing and has, in essence, been adopted by at least two previous investigators.[6,7] The visual target on the white wall was chosen to be relatively small in size (close to a Snellen chart 6/15 line) but having enough contrast to be reasonably visible by individuals with small refractive errors, i.e. it would be expected to be blurred in those with moderate myopic refractive errors. In the present studies, care was taken not to alert the subjects that the specific objective of the studies to assess if their eye blinking changed according to whether or not they had a visual target or how blurred the distant target was from their viewing perspective.

As noted in the introduction, spontaneous eye blink activity has been categorized as being 'blinking of uncertain origin' in that it occurs 'without the intervention of any obvious stimulus to touch, dazzle or menace' and so is considered different to that eye blink activity that occurs when a deliberate stimulus is presented to the eye or other parts of the body (e.g. aural, tactile or even electrical stimuli).[1–3] Within this context, when undertaking experimental studies of this type, it is acknowledged that there could also be many other factors – not even considered in early studies – that could well be considered as potentially important determinants of spontaneous eye blink activity. For example, from a contemporary perspective it could be argued that some of the subjects – while recruited as nominally normal healthy individuals – could have abnormal tear film in terms of stability, osmolarity or evaporation rates or, from a psychophysical perspective, actually engage in the visual task with different degrees of consciousness or level of mental activity that changes over time. However, these are all issues that could be applied to almost all experimental studies on spontaneous eye blink activity and, it is acknowledged, could all contribute to inter-subject variability. Notwithstanding, the overall goal in these studies was to passively assess eye blinking in primary eye gaze in the absence of any demanding visual stimulus or task.

Other investigators have opted for passive viewing in primary eye gaze of much more complex distant 'targets' such as subjects being asked to watch an 'educational film',[10,11] or a 'video' placed 3 m away.[12] It is acknowledged that the viewing environment and target in the present studies is far removed from the natural world but reflects an attempt to standardize the experimental protocols. The use of the small (cross) visual target on a large whiteboard has been used in other studies under constant illumination,[8,13] as well in studies to assess whether sub-threshold exposure to various exogenous stimuli (that could, in themselves, could elicit a reflexive eye blink if presented at super-threshold levels) could affect (alter) the apparent SEBR. One such 'stimulus' could be the illumination in the room in which subjects were being assessed and while moderate differences lighting levels per se appear to have little obvious influence, the presence of some type of distance glare can slightly increase SEBR in primary eye gaze and not talking.[14,15] Notwithstanding, most studies on so-called spontaneous eye blink activity in primary eye gaze do not indicate what a subject had to look at in the distance while observations of SEBR were being made.

For the most of the set of examples used in a systematic review (of what 'normal' SEBR might be in primary eye gaze and who were not in conversation),[1] no actual data is provided on refractive error (RE) of the subjects.[16–29] A few studies note (or imply) the use of spectacles during the SEBR assessments,[6,11,13,17,21,27] or that subjects did not have substantial refractive errors.[10,12] In a later study, subjects with 'mild to moderate' refractive errors (no details provided) were asked to remove their spectacles prior to SEBR assessments whilst sitting in a chair and directing their gaze to a distant target.[9] As noted in the introduction, the rather wide range of apparently normal SEBR values for subjects in primary eye gaze and not talking (with particular reports providing averaged values from 8.5 to 21 eye blinks/min) could be attributed to the different viewing conditions and/or how well subjects might be able to see a distant target. This scenario is presented as very different from when subjects are being asked to concentrate on viewing a near-point monitor screen where, for example, imposed visual blur (at near) can substantially change SEBR.[30] Similarly, it has been accepted since the 1940s that clear vision with a low blink rate is a likely prerequisite for being able to easily read print in books.[31,32] The present studies, for distance vision, indicate that a target could be useful to reduce time-related variability in SEBR assessments but that the effect of distance visual blur is unlikely to be a substantial determinant of the SEBR in primary eye gaze. Stated another way, for subjects not being required to read or decipher text or other symbols in a specific visual task, the detail of the target does not seem to be important (although further studies are needed to verify this).

For the first issue, other studies using a blank wall for visual gaze direction have not indicated whether time-related changes occurred.[6,7] A note was made that time-related changes in SEBR can occur over 5 min which 'usually rose successively, except for a downward turn that sometimes occurred in the 5th minute'.[33] A justification for only making eye blink observations over 3 min was that SEBR was only stable over this period.[34] The present studies provide substantially more information on such possible time-related changes with a noticeable increase in variability occurring over the 5th minute of observations. The reason for both the decreases or especially the increases in SEBR, in healthy emmetropes without any obvious ocular surface disease, remains unknown but could perhaps be related to what might be termed wandering of concentration.[35] Regardless of the reason, the substantially increased intra-subject variability in SEBR (to an average, as the COV, of close to 40%) is at least double that seen for subjects provided with a distant target (i.e. of close to 20% or less). An averaged COV of around 21% has also been observed for other essentially emmetropic subjects being assessed in primary eye gaze and in silence.[15]

For the second issue (i.e. the clarity of a visual target), the present results indicate that any effect of a subject not be able to clearly see a target is only on the order of a 2–4 eye blinks/min and therefore unlikely to account for range of averaged SEBR values for subjects assessed in primary eye gaze and in silence by various investigators.[1] The hyperopes

were assessed as type of negative control in that, overall, their ability to see a 2 m distant high contrast cross should not be substantially different according to whether or not they were wearing their spectacles (even though it could be argued that specific assessments of their actual distance visual acuity using a Snellen chart could have been undertaken). In contrast, for the myopes, that there can be a slight time-related decline in SEBR (e.g. Fig. 4B) might be considered to be somehow related to refractive error. However, that the small set of myopic subjects studied showed only a transient increase in SEBR (when asked to view the distant target without their spectacles) this was not obviously related to their experience of distance visual blur (i.e. in relation to their manifest refractive error). Studies on individuals with greater refractive errors might, however, show larger changes. It is acknowledged that a limitation of the present studies is that observations were only made over the short term and the time course of the imposed distance visual blur (in the myopes) was not precisely standardized. Usually, video recordings were started within a couple of minutes of the subjects being asked to remove their spectacles. However, this was not specifically timed since the examiner took whatever time was considered needed to ensure that the subjects appeared to be settled, to adjust the camera, initialize the camera software for the subject etc.

In conclusion, these studies indicate that a greater minute-by-minute variability in spontaneous eye blink activity might occur if the subjects are not provided with something specific to look at while their SEBR is being assessed in primary eye gaze (and in silence). Stated another way, some form of visual target could be useful for studies on SEBR to limit spontaneous eye movements due to wandering of attention and/or unwanted saccades. However, this visual target perhaps only needs to be something that the subjects retain in their short-term (visual) memory (having seen the target while they wearing their spectacles).

Conflicts of interest

The author reports no conflicts of interest.

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