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Evaluating the use of a temperature sensor to monitor spectacle compliance in warm versus cold climates

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Abstract

Background: This study investigates the utility of a temperature sensor data logger to monitor spectacle compliance for future application in research and clinical settings. Specifically, the question of whether warm versus cold climates negatively impact accuracy of the sensor to monitor spectacle wear is investigated.

Methods: Fifty adults from Houston, Texas (summer) and 40 adults from Columbus, Ohio (winter) wore a thermosensor on their spectacles for one week while keeping wear-time logs. Temperatures during reported spectacle wear (ON) were compared to temperatures during non-wear (OFF) between sites. Two methods to approximate wear time were evaluated by percent error with respect to subject-reported wear time. Method 1 filtered temperatures, classifying the range of 28.4 to 35.2°C as wear. Method 2 utilised examiners interpreting temperature versus time plots. Separate analysis of periods of reported outdoor wear was performed to identify the percentage of time examiners correctly identified wear.

Results: Group mean ON temperatures did not differ between sites ($p = 0.72$), but group mean OFF temperatures were significantly warmer in Houston (Houston: $24.7 \pm 2.0^\circ\text{C}$, Columbus: $20.3 \pm 2.1^\circ\text{C}$; $p < 0.0001$). Median percent error of the filtering technique to approximate subject reported wear time was 4 per cent for Houston and –8 percent for Columbus. Median percent error for examiner 1: Houston 1 per cent, Columbus 0 per cent; median percent error for examiner 2: Houston 3 per cent, Columbus 0 per cent. Houston outdoor wear was correctly identified 88 and 97 per cent of the time by the examiners versus 79 and 81 per cent for Columbus.

Conclusion: Despite environmental temperature differences, measured temperatures during spectacle wear were similar across subjects and median per cent error was less than 10 per cent for both wear time approximation methods. The device studied was effective for objectively

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The authors report no conflicts of interest and have no proprietary interest in any of the materials mentioned in this article. SmartButton data loggers were purchased directly from ACR Systems, Inc. by the authors to conduct the study. There is no relationship between the authors and ACR Systems, Inc., nor was ACR Systems, Inc. involved in the conceptualisation, execution, or presentation of this study.

monitoring spectacle wear in both warm and cold climates with the caveat that subjects spent the majority of time indoors.

Keywords

dose monitoring; objective monitoring; spectacle compliance; thermosensor

[Introduction]

Objective monitoring of patient compliance with prescribed treatments provides valuable information for the clinical management of patients, as well as understanding research outcomes. Strategies have been designed to objectively monitor both ocular patching and spectacle wear to better assess treatment success for individuals with amblyopia.¹⁻⁸ In addition, objective monitoring of spectacle wear may be useful in determining patient preference or dependence upon spectacle prescriptions for conditions such as latent hyperopia. The authors of this manuscript are interested in objectively monitoring spectacle wear time as a surrogate for patient preference of a given prescription in populations with intellectual disability.

Thermosensor data loggers are commercially available devices that autonomously sample and store environmental temperatures at fixed time intervals. Thermosensors are available commercially and commonly used in the food and drug industry to monitor temperature for shipment and storage of temperature-sensitive cargo. Several laboratories have evaluated the ability of thermosensor data loggers to objectively monitor spectacle wear when affixed to spectacles with relatively good success.^{3,5,9} One of the limitations in adopting these devices to monitor spectacle wear is environmental conditions that may mask the ability to observe temperature changes expected as a consequence of spectacle wear.^{3,5,9}

The authors previously reported success approximating spectacle wear time in adult subjects wearing the commercially available Smartbutton Data Logger (*ACR Systems Inc.*, www.acrsystems.com) attached to the side of their spectacles in Houston, Texas during summer months where temperatures routinely exceed 32°Celsius (°C).¹⁰ Wear time was successfully approximated with median percent error less than 10 per cent for both a temperature filtering technique (wear time defined as all time periods corresponding to temperatures between 28.4 to 35.2°C), and an examiner marking technique whereby an examiner viewed temperature versus time plots to identify patterns indicative of spectacle wear.¹⁰

The device was well tolerated by previous study participants. One observed limitation was difficulty discriminating spectacle wear from non-wear when spectacles remained in a warm environment (for example, a parked car) overnight where temperatures were consistent with body temperature.¹⁰ Patient education regarding these issues could alleviate these challenges, making the device immediately deployable for practitioners or researchers wishing to quantify spectacle wear time in patients living in moderate to warm climates.

One concern that remains prior to widespread use of the Smartbutton for spectacle wear tracking is whether the device will be equally successful in monitoring spectacle wear in a

cold weather climate. Given the placement of the sensor on the side of the spectacles and its potential exposure to external conditions, this study questioned whether the sensor would remain insulated by the body and thus reach the same temperatures during periods of spectacle wear in a cold winter climate as compared to a warm summer climate.

In addition, this study sought to determine whether the previously published temperature range indicating spectacle wear in the Houston cohort could be applied to participants in a cold winter climate when filtering data to approximate spectacle wear time. The outcomes from this study will provide practitioners and researchers from diverse environmental climates a better understanding of the likely success or possible limitations of utilising the Smartbutton to monitor spectacle compliance.

Methods

Subjects

The study protocols were approved by the Institutional Review Board for the Protection of Human Subjects at the University of Houston and the Ohio State University, and the research was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained from all study participants.

Subjects were adults (18 years or older) recruited from the students, faculty, and staff at the University of Houston College of Optometry (UHCO) and the Ohio State University College of Optometry, as well as family members, friends, or acquaintances of the study investigators.

Subjects were requested to wear their spectacles for at least 10 hours per week throughout the study, and full-time wear was not permitted to avoid predictable wear patterns from the dataset. Data for subjects in the Houston and Columbus cohorts were collected in the summer of 2014 and winter of 2016, respectively.

Description of thermosensor device and mounting strategy

The *Smartbutton Data Logger* used in this study is a commercially available thermosensor that passively obtains and stores temperature readings at fixed time intervals of 1 to 255 minutes. The sensor is capable of measuring temperatures ranging from -40 to 85°C with a resolution of 0.5°C . Prior to conducting the study, the variability of sensors was evaluated by leaving 25 sensors in a fixed temperature environment for 17 hours. Over the 17-hour period, the mean and standard deviation measured temperature from all sensors combined was $20.2 \pm 0.16^{\circ}\text{C}$. Sixteen sensors had individual variations within a total range of 0.5°C and 9 sensors varied over a total range of 1°C .

The *Smartbutton Data Logger* is 4 g in weight, 17.35 mm in diameter, and 5.89 mm in height. The specifications of this low-voltage device have been described in detail previously.¹⁰ The internal memory of the sensor is retrieved through a USB interface connected to a computer with *Trendreader for Smartbutton Software* (ACR Systems Inc.,

www.acrsystems.com), which extracts the data into a spreadsheet with recordings of temperature and the corresponding time-stamp, as well as a plot of temperature versus time.

The subjects wore the temperature sensor for one week and temperature data were then extracted from the sensor for the entire week of wear. The temperature sensors were mounted to the spectacles of the subjects using a custom designed silicone sleeve (UHCO Technical Services) that held the sensor behind the ear of the subject, either above or below the area between tip and drop of the spectacle side.¹⁰

Data collection

Subjects wore their spectacles with the sensor for at least 10 hours per week, and completed daily paper logs, documenting specific times when the transitions of spectacles (ON/OFF or OFF/ON) occurred. Documentation of additional details regarding the environment and subject activities, such as whether the subject was indoors or outdoors, was encouraged. It was recommended to subjects that they use electronic devices to assist in the accuracy of documentation (for example, recorded voice prompts with time stamps), and to transfer the information daily to the log sheets. An example spectacle wear-time log was provided to participants at the beginning of the study.¹⁰

The instructions to participants in Columbus and Houston were the same to ensure comparability. Subjects were instructed to wear spectacles a minimum of 10 hours per week and encouraged to perform activities, including leaving spectacles in different places, that might prove challenging for the investigators to discern spectacle wear.

The sampling interval of the sensors was set for recording time-stamped temperatures every five minutes, which allowed capture of 288 temperature samples per day and storage of data for seven days. The five-minute sampling interval was set to allow collection of one week of data at a time and to ensure consistency between Columbus and Houston.¹⁰

Sample size

Given that this study investigated a device with a new application, there were no previous data from which to calculate a sample size. Fifty subjects from Houston and 40 subjects from Columbus were recruited for the study in an attempt to include a wide variety of participants who might engage in varied activities while wearing the device.

Data analysis

The outdoor temperatures in Houston and Columbus during the study periods were retrieved from weather.com, and the average low and high temperatures were compared between Houston and Columbus using two-sample t-tests.

Temperatures recorded with the temperature sensor during times that the subject log indicated the spectacles were being worn were classified as ON, and temperatures during times when spectacles were documented as not being worn were classified as OFF. The mean ON and OFF temperatures for all subjects were compared between study sites (two-sample t-test). The recorded temperatures by the sensor during times when the subject reported that the spectacles were worn served as truth for temperature data for each subject.

The spectacle wear-time logs were graded for confidence (high, medium, low) using a standardised confidence grading criterion across sites as described previously.¹⁰ Briefly, three characteristics of the logs were evaluated: 1) whether all of the time in the week was accounted for; 2) whether documented times were specific and clear; and 3) whether environmental details were provided. Logs were categorised as high-confidence if all three characteristics were present throughout the log, medium-confidence if one of the three characteristics was missing consistently throughout the log, and low-confidence if two or more of the three characteristics were missing throughout the log, or if the log appeared to be poor quality (for example, illegible) and/or the logs were filled out at the time of the follow-up visit.

Two strategies were used to approximate spectacle wear time in this study: a temperature filtering method and examiner inspection of temperature versus time plots using custom software (Temperature Log Viewer 1.2, UHCO Core Programming Module). A temperature range of 28.4 to 35.2°C was used to classify spectacle wear for the filtering method. This temperature range was previously established using the mean and 1.5 standard deviations of the ON temperatures calculated for the entire group in Houston,¹⁰ and thus applying this range to both cohorts allowed evaluation of the performance of a fixed temperature range across climates.

Regarding the examiner inspection method to approximate spectacle wear time, specific details regarding this method have been described previously.¹⁰ Briefly, two masked examiners (the same for both Houston and Columbus) independently analysed temperature versus time plots without knowledge of any information from the subject-reported wear time. Plots were analysed using Temperature Log Viewer 1.2, from which the examiners identified and marked transitions that they believed to correspond to spectacles being put on or taken off. Specifically, visual inspection of sharp increases/decreases in temperature were identified as transitions between wear and non-wear. Noise (small fluctuations) of the data trace occurring when temperatures were around body temperature were identified as periods of wear, whereas flat/stable temperature readings were considered to be driven by the environment and identified as periods of non-wear (Figure 1). The total spectacle ON time based on the markings of the examiners on the temperature versus time plots was then calculated by the software and compared to the ON time reported by the subject.

To evaluate the success of each method to approximate spectacle wear, individual percent error was calculated using Equation 1 below for each approximation strategy for all subjects at both sites. Percent error was then categorised as 10 per cent, > 10 to 20 per cent, and > 20 per cent error. Chi-square analysis was performed to compare the distributions of percent error in approximated wear time using different strategies within each site and between the two sites; Fisher's exact tests were used instead when the expected cell frequency in the contingency table was fewer than five. Friedman tests were performed to compare the median percent error across different methods within each site, and the median percent error for each method was compared between the two sites using Wilcoxon rank sum tests.

$$\text{Percent Error} = \left(\frac{\text{Approximated ON Time} - \text{Subject Reported ON Time}}{\text{Subject Reported ON Time}} \right) \times 100$$

EQUATION 1

A separate analysis of only periods of time where subjects reported the spectacles were outside (either worn or not worn) was conducted to compare the ability of the two examiners to correctly identify wear and non-wear during outdoor environmental exposure. For this analysis, all periods of outdoor wear and non-wear for all subjects combined were grouped by study site and the percentage of time each examiner correctly identified wear or non-wear compared in a descriptive analysis.

Results

Fifty adults (32 female, 18 male) from Houston and 40 adults (28 female, 12 male) from Columbus completed at least 10 hours of temperature sensor wear for one week and were included in data analysis. Data were collected from 30 May to 18 July 2014 in Houston and from 5 January to 15 February 2016 in Columbus. The average outdoor temperatures were significantly higher in Houston (low: $24 \pm 1^\circ\text{C}$, high: $32 \pm 2^\circ\text{C}$) than in Columbus (low: $-6 \pm 6^\circ\text{C}$, high: $4 \pm 8^\circ\text{C}$) for both the low ($p < 0.001$) and high ($p < 0.001$) temperatures during the study periods.

Spectacle ON and OFF temperatures were classified by merging data logger time stamps extracted from data sensors with subject reported on and off spectacle wear times from their activity logs. The average ON temperature was not significantly different between Houston and Columbus (Houston: $31.9 \pm 1.7^\circ\text{C}$, Columbus: $31.8 \pm 1.4^\circ\text{C}$; $p = 0.72$), but the average OFF temperature was significantly higher in Houston than in Columbus (Houston: $24.7 \pm 2.0^\circ\text{C}$, Columbus: $20.3 \pm 2.1^\circ\text{C}$; $p < 0.001$). The range of ON temperature was 19.5 to 55.0°C for Houston and 2.5 to 40.5°C for Columbus, respectively; the range of OFF temperature was 18.0 to 72.5°C for Houston and -5.5 to 35.5°C for Columbus, respectively (Figure 2).

It should be noted that the extreme temperatures (less than 0°C and greater than 40°C) likely occurred intermittently during transitions from non-wear to wear. Given that these extreme temperatures were experienced so infrequently (0.02 per cent or less of all recorded temperatures), they were not visible at the scale used for Figure 2, and thus the x-axis was truncated to allow better visualisation of the more common temperatures.

Accuracy of approximation methods

Figure 3 shows the histograms of percent error in approximated wear time using different strategies (filtering method and examiners approximating wear time). The range of percent error in Houston was -58 per cent to 148 per cent for the filtering method, -54 per cent to 62 per cent for Examiner 1, and -54 per cent to 59 per cent for Examiner 2, respectively; the range of percent error in Columbus was -30 per cent to 16 per cent for the filtering method,

–16 per cent to 14 per cent for Examiner 1, and –35 per cent to 10 per cent for Examiner 2, respectively.

The absolute values of percent error were classified into three categories: 10 per cent Error, 11–20 per cent Error, and > 20 per cent Error in Table 1. All spectacle wear-time logs were included in the statistical analysis, but a subset of subjects (all those with high-confidence logs) were further analysed to evaluate potential impact on the percent error by log quality (Table 1). The distribution of absolute percent error based on the classifications shown in Table 1 was not significantly different across the three strategies for the 50 subjects in Houston ($\chi^2 = 1.41$, $p = 0.84$) or for the 40 subjects in Columbus (Fisher's exact test, $p = 0.06$). However, the median percent error was significantly different across the three methods for Columbus (Friedman test, $\chi^2 = 40.95$, $p < 0.001$), although not significantly different for Houston (Friedman test, $\chi^2 = 0.84$, $p = 0.66$).

Pairwise Friedman's tests revealed that for Columbus, the filtering method had more negative percent error (indicating an underestimation of wear time) than both Examiner 1 and Examiner 2 ($p < 0.001$), while there was no difference between Examiner 1 and Examiner 2 in the median percent error (Friedman test, $\chi^2 = 0.90$, $p = 0.34$).

When comparing the filtering method between Houston and Columbus (Table 1), the distribution of absolute percent error was not significantly different between the two sites (Fisher's exact test, $p = 0.17$). However, the distribution of absolute percent error was significantly different between the two sites for both Examiner 1 (Fisher's exact test, $p = 0.01$) and Examiner 2 (Fisher's exact test, $p = 0.01$), with more 10 per cent error and fewer > 20 per cent error distributed in Columbus than Houston for both examiners. The median percent error was significantly different between Houston and Columbus for the filtering method (Houston: 4 per cent, Columbus: –8 per cent; Wilcoxon rank-sum test, $Z = 5.71$, $p < 0.001$), indicating a tendency of overestimation of wear time in Houston and underestimation of wear time in Columbus. Examiner 2 had more positive median percent error for Houston than Columbus (Wilcoxon rank-sum test, $Z = 2.18$, $p = 0.03$), while the median percent error was not significantly different between Houston and Columbus for Examiner 1 (Wilcoxon rank-sum test, $Z = 1.47$, $p = 0.14$).

Examiner approximations of wear time were within an accuracy of 0 to 20 per cent error for about 80% of subjects from Houston for the filtering method and both examiners, while all of these strategies had < 20 per cent error for more than 90 per cent of subjects from Columbus (Table 1). The overall magnitude of error for the subjects falling outside of ± 20 per cent error was greater for the filtering methods compared to examiner approximation and also greater for Houston than Columbus.

For Houston, the median absolute percent error for the subjects falling outside of ± 20 per cent error was 67 per cent for the filtering method, 34 per cent for Examiner 1, and 32 per cent for Examiner 2, respectively. For Columbus, only three subjects fell outside of ± 20 per cent error for the filtering method, all subjects were within an accuracy of 0–20 per cent error for Examiner 1, and only one subject fell outside of ± 20 per cent error for Examiner 2. Percent error by examiner approximation was less than 100 per cent for all subjects, whereas

the filtering method had three instances of percent error exceeding 100 per cent, all of which were positive errors and occurred in Houston.

Results of the subgroup with high-confidence logs

Results from the subset of subjects with high-confidence logs show comparable median and quartile of percent error and similar trend in the distribution of absolute percent error compared to the results from the whole sample for each approximation method (Table 1). However, the distribution of absolute percent error shifted towards the ≤ 10 per cent error category when limiting to the high-confidence logs, indicating an improvement in ability to accurately predict wear time.

Results of outdoor data

Not all subjects reported periods of outdoor exposure of the glasses. For the subjects who reported periods of wearing glasses outdoors (outdoor wear) and/or periods of having glasses outdoors when they were not being worn (outdoor non-wear), examiner ability to correctly identify wear or non-wear is summarised in Table 2. For outdoor wear, the average temperature recorded by the sensor of all outdoor samples was $28.5 \pm 4.7^{\circ}\text{C}$ for Columbus and $32.2 \pm 2.7^{\circ}\text{C}$ for Houston, respectively. The percentage of samples the examiners correctly identified as wear was 81 and 79% for Columbus for each examiner and 97 and 88% for Houston. For outdoor non-wear, the average temperature recorded by the sensor of all outdoor samples was $18.2 \pm 5.5^{\circ}\text{C}$ for Columbus and $30.6 \pm 1.7^{\circ}\text{C}$ for Houston, respectively. The percentage of samples the examiners correctly identified as non-wear was 95 and 92 per cent for each examiner for Columbus and 11 and 0 per cent for Houston, respectively.

Discussion

The study results show that the SmartButton Data Logger is an effective device to objectively monitor spectacle wear time in both warm and cold weather climates. Despite environmental temperature differences, measured temperatures during spectacle wear were similar across subjects and median percent error was less than 10 per cent for all wear time approximation methods.

One limitation to the above conclusion is that subjects at both sites spent the majority of their time indoors, limiting the exposure of the sensor to the more extreme ranges of environmental temperatures, and effectively rendering the two environments more similar (climate controlled indoor settings). Despite that, periods of outdoor wear totalling between 45 and 65 hours in both Houston and Columbus were still detected by examiners with approximately 80 per cent or greater accuracy at each site.

Regarding the filtering method to identify periods of spectacle wear, this method categorised wear time from a temperature range previously determined from the Houston cohort (28.4 to 35.2°C), which defined spectacle ON time as temperatures falling within the entire group mean ± 1.5 standard deviations of ON temperatures.¹⁰ Since the average ON temperature was not significantly different between Houston and Columbus, it is expected that a filtering temperature range determined from the Columbus data using the same method as the

Houston data would result in a similar range, and thus this analysis was not pursued. However, if a patient population who spends substantially more time outdoors in a cold environment were monitored with the Smartbutton, this filtering range may not be appropriate, as evidenced by the lower mean temperature for outdoor spectacle wear in the Columbus cohort (Table 2).

As was previously reported for the Houston data,¹⁰ examiner inspection of the plots yielded better estimates of wear time compared to the filtering method. The filtering method had significantly more negative median percent error than both examiners in Columbus. For Houston, although the median percent error was not significantly different between the two methods, the overall magnitude of error for the subjects in Houston falling outside of ± 20 per cent error was much greater for the filtering methods. In addition, examiner inspection of plots yielded accurate detection of outdoor wear for both sites at approximately 80 per cent detection or better. Twenty percent error is considered to be an acceptable threshold when monitoring compliance of full-time spectacle wear, given that a 20 per cent underestimation for a 16-hour waking day would still estimate 12.8 hours of wear, which is substantially longer than part time.¹⁰ For patient populations for whom short durations of wear are prescribed, this threshold of error may not be adequate to monitor compliance.

This study was conducted with adult subjects recruited primarily from University settings who happened to spend little time outdoors, and thus the conclusions regarding the success of the device may not be generalisable to other populations. Adults were selected for participation due to the necessity to obtain detailed wear time logs to validate the device, a study design requirement which is unlikely to be obtained from children. However, there is not a strong reason to believe that children would be less tolerant to wearing the sensor, or that the sensor would perform less robustly when worn by a child.

With respect to subjects who have primarily outdoor occupations or children spending significant time outdoors, further study may be needed to validate the utility of the technique, although the data suggest that the examiner inspection technique would remain robust. The environmental condition that proved most problematic for successful identification of spectacle wear or non-wear was outdoor non-wear. Leaving spectacles outdoors when not wearing them is an unlikely behaviour and one that may have been observed due to the examiners encouraging the subjects to try activities that might make it difficult to discern wear versus non-wear. For future application of the device, investigators or practitioners could counsel patients to avoid this behaviour.

Due to the amount of time that transpired between collection of the Houston and Columbus datasets, the authors sought to determine whether the Columbus data had better overall percent error due to an examiner learning effect in evaluating the temperature versus time plots. To address this concern, the same two examiners independently viewed and re-marked the plots for a subset of 27 subjects from the Houston dataset two years after their initial analysis. There were no significant differences in the percent error between the first and second grading (paired t-test; $p = 0.46$ for Examiner 1 and $p = 0.25$ for Examiner 2), suggesting it is unlikely that an examiner learning effect accounted for the improvement in performance for the Columbus data.

Conclusion

The temperature sensor data logger can be used to monitor spectacle wear time with an accuracy of < 20 per cent error for the majority of wearers engaging in primarily indoor activities in both warm and cold climates. For individuals spending large amounts of time outdoors, hot environments that exceed 32°C may interfere with the ability to monitor spectacle wear, due to the opportunity for the spectacles to reach temperatures consistent with body temperature during times of non-wear. Additional validation of the sensor is needed for this subset of individuals.

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Figure 1.

Example of examiner markings on a temperature versus time plot. The green dashed lines indicate examiner interpreted transitions of spectacles on and the red dashed lines indicate transitions of spectacles off. Note this plot was generated with graphing software rather than Temperature Log Viewer 1.2 to provide better image resolution.

Figure 2.

Histograms of ON and OFF temperatures in Houston and Columbus during the study periods. Note: the total range of temperatures recorded was -5 to 72.5°C ; however, some of the extreme temperatures were so rarely observed that they could not be visualised on the plot at the scale that best visualised the primary groups of data, and thus the axes are truncated to 0 and 40.

Figure 3.

Histograms of percent error in approximated wear time using three different approximation strategies for A: Houston, Texas and B: Columbus, Ohio

Table 1.

Classification of absolute percent error and median error in approximated wear time for all logs and high-confidence logs (light grey areas) using three different approximation methods for Houston, Texas and Columbus, Ohio.

	Filtering Method		Examiner 1		Examiner 2	
Houston, Texas	All logs (n = 50)	High-confidence logs (n = 15)	All logs (n = 50)	High-confidence logs (n = 15)	All logs (n = 50)	High-confidence logs (n = 15)
Median Error (Quartile 1, Quartile 3)	4% (-2%, 19%)	7% (-1%, 19%)	1% (-3%, 13%)	1% (-1%, 7%)	3% (-3%, 10%)	3% (-3%, 10%)
10% Error	n = 29 (58%)	n = 9 (60%)	n = 34 (68%)	n = 12 (80%)	n = 32 (64%)	n = 12 (80%)
11–20 % Error	n = 10 (20%)	n = 3 (20%)	n = 7 (14%)	n = 2 (13%)	n = 7 (14%)	n = 3 (20%)
> 20% Error	n = 11 (22%)	n = 3 (20%)	n = 9 (18%)	n = 1 (7%)	n = 11 (22%)	n = 0 (0%)
Columbus, Ohio	All logs (n = 40)	High-confidence logs (n = 17)	All logs (n = 40)	High-confidence logs (n = 17)	All logs (n = 40)	High-confidence logs (n = 17)
Median Error (Quartile 1, Quartile 3)	-8% (-14%, -4%)	-8% (-11%, -4%)	0% (-3%, 3%)	1% (0%, 3%)	0% (-3%, 2%)	1% (-1%, 3%)
10% Error	n = 27 (68%)	n = 12 (71%)	n = 34 (85%)	n = 16 (94%)	n = 36 (90%)	n = 17 (100%)
11–20 % Error	n = 10 (25%)	n = 4 (24%)	n = 6 (15%)	n = 1 (6%)	n = 3 (8%)	n = 0 (0%)
> 20% Error	n = 3 (8%)	n = 1 (6%)	n = 0 (0%)	n = 0 (0%)	n = 1 (3%)	n = 0 (0%)

Table 2.

Summary of outdoor data for subjects who reported periods of wearing spectacles outdoors, or periods of leaving spectacles outdoors when they were not being worn.

	Outdoor wear		Outdoor non-wear	
	Columbus	Houston	Columbus	Houston
Total subjects	n = 34	n = 29	n = 4	n = 4
Total temperature samples	n = 739	n = 545	n = 38	n = 90
Average duration of outdoor exposure (minutes)	35	90	20	113
Shortest duration (minutes)	10	5	15	50
Longest duration (minutes)	170	350	30	155
Mean $\pm$ SD recorded temperature ($^{\circ}$ C)	28.5 $\pm$ 4.7	32.2 $\pm$ 2.7	18.2 $\pm$ 5.5	30.6 $\pm$ 1.7
Recorded temperature range ($^{\circ}$ C)	11–39	22.5–38.5	9.5–32	24.5–33.5
Percent correct classification of wear or non-wear Examiner 1	81%	97%	95%	11%
Examiner 2	79%	88%	92%	0%