Title: Effects of optical correction method on the magnitude and variability of accommodative response: A test-retest study.

Authors: Raimundo Jiménez, PhD[1]; Beatriz Redondo, MS[1]; Leon N. Davies, PhD[2] & Jesús Vera, PhD[1*]

Affiliations:

1. Department of Optics, University of Granada, Spain.
2. Ophthalmic Research Group, School of Life and Health Sciences, Aston University, Birmingham, UK

Corresponding author: Jesús Vera, Department of Optics, Faculty of Science, University of Granada, Campus de la Fuentenueva 2, 18001 Granada, Spain. Tel: +34 95824440675. Fax: +34 958248533. E-mail: jesusvv@correo.ugr.es.

Number of words: 4732

Number of tables: 2

Number of figures: 4

Introduction

The accommodative response is defined as the ocular ability that allows people to see clearly at different distances,[1] and its measure constitutes an important part of the optometric examination. An inaccurate accommodative response can be derived from an imperfection in a neural integrator in the accommodation control system,[2] as a consequence of different circumstances such as trauma,[3] systemic and ocular pathological conditions,[4,5] pharmacological therapy,[6,7] neurological abnormalities,[8] refractive condition,[9] amblyopia,[10] and binocular and accommodative dysfunctions.[11]

Under-accommodation is termed as accommodative lag. However, at near distances, a value ≤ 0.75 D is considered clinically normal since it does not usually surpass the depth of focus, with individuals rarely aware of a lack of sharpness in focus.[12,13] In this regard, the presence of a higher lag of accommodation may lead to ocular asthenopia and accommodative fatigue during prolonged near activities.[14,15] Also, there are some studies that have suggested a link between accommodative lag and myopia progression, although, this fact is still a matter of debate.[16–21] Consequently, a study examining factors that may modify the accommodative response is of significance for the understanding and management of ocular asthenopia and myopia progression.

Several studies have suggested that the use of single vision soft contact lenses versus spectacles could modify accommodative and binocular function,[22–25] as well as everyday visual functioning.[26] However, the use of soft contact lenses permits a central and peripheral visual performance similar to spectacles.[27] Relevantly, the concept of 'accommodative unit' introduced that the different vertex distances between both optical correction methods (e.g., soft contact lenses and spectacles), as well as the back vertex power, are known to vary the accommodative demand and response.[28] This concept needs to be addressed to determine the real accommodative stimulus and response when wearing different optical devices

In clinical practice, methods such as Cross retinoscopy, monocular estimate method retinoscopy or Nott dynamic retinoscopy (see Locke & Somers[29] for a description of these methods) are commonly used to assess the accommodative response,[29] however, there is no agreement as to which is the optimum technique.[31–33] The recent incorporation of autorefractometers in clinical and research settings has allowed investigators to obtain more reliable measures of static and dynamic accommodation.[32,34–36] In this regard, Hunt et al.[23] used an open field autorefractor, to quantify the accommodative response of young individuals rendered functionally emmetropic with either with soft contact lenses or spectacles, while viewing both static and oscillating targets. Data from Hunt's study supported previous scientific evidence that there are different accommodative and vergence requirements between soft contact lenses and spectacles, and these changes are dependent on the refractive error.[22]

Interestingly, when focusing on a stationary target, the accommodative response fluctuates dynamically (by ~0.50 D). In turn, continuous measurement of accommodation allows the frequency and magnitude of these accommodation fluctuations to be quantified.[37] Hitherto, despite the fact that these instruments allow dynamic assessment of the binocular accommodative response, they have yet to be used to assess the possible differences in the magnitude and variability of the accommodative lag over time with the use of soft contact lenses versus spectacles while viewing stationary targets. These potential differences may have significant implications in a variety of visual conditions (e.g., visual fatigue, myopia progression), as for the magnitude of the accommodative response.

The present study evaluated the influence of wearing soft contact lenses or spectacles on the accommodative response at five different near distances (50, 40, 33, 25 and 20 cm) in two different days in a counterbalanced manner; this evaluation was performed twice in order to assess the repeatability of these results. Here, our first objective was to assess the magnitude and variability of the dynamic binocular accommodative response when wearing soft contact lenses in comparison to spectacles at different near distances, and second, to test the repeatability of the magnitude and variability with a second identical intervention. We hypothesized that (1) the accommodative response as measured with soft contact lenses would be lower (higher lag of accommodation) and show higher variability in comparison to the spectacles condition, and these differences would be greater at closer viewing distances (higher accommodative demand), and (2) the repeatability of these differences for both optical correction methods would be high when measured under the same experimental conditions. Data from this study may be of interest since the differences in the magnitude of accommodation are directly linked to asthenopia, and possibly to myopia progression.[14–20] For its part, alterations in the variability of accommodation have been considered interesting not only for their possible role in the control of accommodation,[37] but also for the association with symptomatic individuals.[38]

Methods

Ethical approval and participants

The study was conducted in line with the tenets of the Declaration of Helsinki and was approved by the University of Granada Institutional Review Board. All volunteers were informed about their right to leave the experiment at any moment and gave an informed consent prior to the commencement of the study.

We performed an *a priori* power analysis for a power level of 0.90 and alpha of 0.05 to determine the minimum sample size based on data from a similar study.[25] According to these assumptions, the size of the study population should be 16 participants. Thirty-eight individuals initially volunteered to participate in this study. Before starting the experiment, a board certified optometrist examined all subjects to screen any symptomatology, ocular pathology, as well as general conditions that could affect accommodative response. Hence, the inclusion criteria were (see Table 1 for more details): 1) the absence of any ocular disease, 2) belong to the asymptomatic group as measured with the Conlon survey (cut off value of ≤24),[39] 3) a best-corrected distance visual acuity ≤0.00 log MAR (20/20 Snellen) in each eye, 4) be free of any binocular or accommodative dysfunction following the recommendations of Scheiman & Wick[40], 5) be soft contact lenses and spectacles users at least for one year, 6) anisometropia

<2.00 D, 7) score a value <3 with the Stanford Sleepiness Scale (SSS) to check the level of alertness prior each experimental session,[41] and 8) present an accommodative lag < 1.55D, using an autorefractor, at 20 cm, as indicated by Wang & Ciuffreda[12].

Six out of 38 participants failed the initial screening, and 32 university students were enrolled in this study. We decided to use each participant as his or her own control, thus avoiding undesirable inter-subjects variability or insufficient sample size as consequence of attrition during the course of the study. Additionally, participants were asked to abstain from alcohol and caffeine-based drinks 24h and 12h, respectively, before experimental sessions, refrain from reading and mobile phone use one hour before each session, and to sleep at least 7h the night prior of attending to the laboratory.

Then, 11 out of the 32 enrolled subjects had to be excluded during the main trials of the study. Two participants were excluded because they reported a value higher to 3 at the SSS at the beginning of one experimental session, four individuals did not complete all the experimental sessions, three participants did not obtain the imposed criteria of monocular visual acuity while wearing soft contact lenses (see below), one participant presented a lag of accommodation higher to 1.55 D at 20 cm, and one participant exhibited numerous recording errors (more than 50%) due to reflection, and therefore, they were removed from further analysis. As a result, we analysed data from 21 (mean age (standard deviation) = 21.45 (2.26) with an age range of 19 to 26 years, 8 males and 13 females) out of 32 participants. Baseline characteristics without optical compensation of the study sample were: an average spherical equivalent refractive error (standard deviation) of -0.79 (1.39) D, ranging from -3.25 to +2.75 D (16 myopes and 5 hyperopes).

Procedure

All participants presented to the lab on six different occasions. On the first visit, each participant received a full optometric examination which included objective ocular refraction and keratometry using an auto-keratorefractometer (WAM-5500, Grand Seiko Co. Ltd., Hiroshima, Japan), with the mean value from three measurements calculated. Subsequently, a full monocular and binocular subjective refraction, using an endpoint criterion of maximum plus consistent with best vision, using a bichromatic test, was performed. This new optical correction was used for spectacles and soft contact lenses, considering the appropriate vertex distance adjustments. In addition, we assessed accommodative and binocular function following the recommendations of Scheiman & Wick[40], and examined the presence of any ocular pathology by slit lamp and direct ophthalmoscopy examination. Eye dominance was determined by hole-in-the card method,[42] since this eye was used to obtain the accommodative response measurement.

At the second session, soft contact lenses were individually fitted, considering the corneal measures and exact refraction compensated for vertex distance. Disposable HEMA and Ocufilcon D (55% water content) spherical and toric soft contact lenses were used to compensate astigmatism errors ≤ 0.75 D and astigmatism between 0.75 D and 2.00 D, respectively. A combination of myopia with less than 0.75 D astigmatism was corrected with appropriate spherical equivalent, being the same procedure performed with spectacles in order to match the possible residual errors in both optical correction methods. Participants wore the soft contact lenses for one hour, and a fitting evaluation and an over-refraction (as in session 1) were performed in order to ensure appropriate visual comfort and performance with the lenses. In addition, an appropriately centred lens with adequate post blink movement, and distance visual acuity ≤0.00 logMAR (20/20 Snellen) in each eye were required for participants to continue in the study.

The next four visits (3 to 6) comprised the main experimental protocol. Here, the accommodative response at five different distances (50, 40, 33, 25, and 20 cm) was measured in a fixed order (from far to near distances) when wearing soft contact lenses and spectacles. Participants presented to the lab with soft contact lenses or spectacles in randomized order, and this protocol was repeated twice (trial 1 and trial 2) in order to explore the intersession repeatability of both conditions. For the session with soft contact lenses, participants were asked to wear them for at least one hour and less than four hours before attending to the lab. Participants were instructed to avoid the use of soft contact lenses during the entire day in which they were tested while wearing spectacles.

Experimental design

The study followed a repeated measures design to test the effect of wearing soft contact lenses or spectacles on the accommodative response (magnitude and variability). The accommodative distance (50, 40, 33, 25 and 20 cm) and the optical correction method (soft contact lenses or spectacles) were the within subjects factor. Importantly, to avoid the possible effect of diurnal variations on accommodative response,[33] all experimental sessions were scheduled at the same hour (±1h) for each participant. To evaluate the differences in accommodative response while wearing soft contact lenses and spectacles (reproducibility), we used the mean value from both trials in each experimental condition (soft contact lenses and spectacles), whereas the two identical trials carried out with each optical correction method were individually considered to assess the intersession repeatability.

Dynamic accommodative response assessments

In the present study, we used the WAM-5500 autorefactor, which has been demonstrated to be an accurate tool for quantifying accommodation in both static and dynamic modes, and in different contexts and experimental conditions.[34,35,43–45] The WAM-5500 can acquire continuous recordings of accommodation and pupil size in the dynamic mode (high-speed), with a sensitivity of 0.01 D and 0.1 mm, respectively, and a temporal resolution of approximately 5 Hz.[35] Accommodative response can be measured for a set time interval and distance and, therefore, the magnitude and intra-measure variability from a continuous accommodation response to a static near target can be evaluated. This instrument permits binocular open-view but accommodative response measures are only obtained from one eye at the time, and in this study the dominant eye was chosen to record data.[46] Before commencing all experimental sessions, we performed a monocular static refractive measure in both eyes (considering the mean value from ten measures) to obtain a baseline refractive value, which would be used during data analysis. For all the measures, participants were asked to position their chin and forehead on the respective supports, and viewed a photopic high contrast Maltese cross target aligned on the midline of the head through the 12.5 x 22cm open-field beam-splitter. For the dynamic measurement of accommodative response with spectacle correction the subjects used a half-eye trial frame, which were adjusted for their interpupillary distances and pupil heights to avoid prismatic effects. We used narrow metal-ring trial lenses in order to (1) optimise the WAM's centration and focus, (2) reduce the possible effects of proximal accommodation, and (3) not restrict the visual field. All these effects may be expected by the use of reduced aperture lenses.

Dynamic binocular accommodative response was recorded continuously during 31sec at each of the five accommodative demands; however, the first second was removed to eliminate transient effects from the stimulus onset,[47] and a three minute break between measures was given to avoid accommodative adaptation.[48] Participants looked at a 2-cm high-contrast Maltese cross (Michelson contrast of 0.79). The viewing angle of the target at the five different distances was 2.29, 2.86, 3.47, 4.58, and 5.73º, for the accommodative distances of 50 cm (2 D), 33 cm (3 D), 25 cm (4 D), and 20 cm (5 D), respectively. During the measurement, the subjects were asked to keep the target as clear as possible. Possible blinking or recording errors were identified as all those values varying more than 3 standard deviations from the mean, and these values were removed from further analysis.[15,49] At the beginning of each experimental session, we measured baseline static refractive errors, using the autorefractometer, in order to correct any potential diurnal changes in the over-refraction. For the calculation of the lag of accommodation, as indicated by Poltavski, Biberdorf & Petros[50], we subtracted the mean value from the dynamic measures and the baseline static refractive value obtained in far distance to the accommodative demand at each distance (2, 2.5, 3, 4 and 5 D). As the presence of an ophthalmic lens changes both the accommodative stimulus and the measured accommodative response, all measurements obtained with spectacles were referred to the corneal plane, following the equations 5e and 8e provided in the study of Atchison and Varnas[51]. The target distances were always constant, however, the accommodative demand is modified when the stimulus is viewed through ophthalmic lenses in comparison to the target distance. In order to eliminate this confounding factor, the ophthalmic lenses were placed at a vertex distance of 12 mm, as measured by the app (MyCenter, Tematica software, Spain) installed in an iPad 3 (Apple, Inc., Cupertino, CA), and using the different holders of the trial frame in order to adjust them for the desirable vertex distance (12 mm). The base luminance of the target was 31 cd m−2, and room illumination conditions were kept constant across sessions (approximately 150 lx, range: 145 to 155 lx).

Statistical Analysis

First, two separate two-way repeated measures analysis of variance (ANOVA) was conducted to test the differences in the magnitude and variability (standard deviation during each dynamic accommodative response measurement) of accommodative response, respectively, considering the optical correction method (spectacles and soft contact lenses) and the viewing distance (50, 40, 33, 25, 20 cm) as the within-participants factors. The mean values from both trials were used for statistical analyses of both dependent variables (magnitude and variability of accommodative response). Also, separate linear regression analyses for each viewing distance were performed to assess the possible relationship between participant´s refractive error and the differences in the accommodative response (magnitude and variability) between both optical correction methods (spectacles and soft contact lenses). The magnitude of the differences was calculated by partial eta squared (η_p^2), and the Holm-Bonferroni correction[52] for multiple comparison was used where applicable as indicated by Armstrong[54].

Second, to examine inter-methods (spectacles and soft contact lenses) reproducibility, paired two-tailed t-tests were employed to determine the differences between both optical correction methods for each distance (50, 40, 33, 25 and 20 cm). Similarly, to test inter-sessions (trial 1 and trial 2) repeatability, we performed paired two-tailed t-tests for each comparison between both trials with both optical correction methods and distance. Following the recommendation of McAlinden et al.[54], we checked that there were no statistically significant mean differences across comparisons. The magnitude of change between methods and sessions were expressed as a standardised mean difference (Cohen´s d effect size), and they were interpreted as: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, and >2 = very large.[55] If the differences were insignificant, the Pearson product moment correlation coefficients and the intraclass correlations coefficients were used to assess the correlation between the two methods of optical correction and the two identical experimental sessions (trial 1 and trial 2).[54]

Lastly, we used the Bland and Altman method[56] to evaluate the mean differences between both methods of optical correction (spectacles and soft contact lenses) and sessions (trial 1 and trial 2).

Results

Before any statistical analysis, the normal distribution of the data (Shapiro-Wilk test) and the homogeneity of variances (Levene's test) were confirmed (p>0.05).

Magnitude of accommodative response differences

The lags of accommodation obtained from the 30 sec dynamic accommodative measure were used to explore the differences in the magnitude of accommodative responses for the two optical correction methods (soft contact lenses and spectacles) at the five distances tested (50, 40, 33, 25, and 20cm), using the average value from Trial 1 and 2. The optical correction method showed statistical significance with greater lags of accommodation for the soft contact lenses in comparison to spectacles ($F_{1,20} = 5.140$, $p = 0.035$, $\eta_p^2 = 0.204$), and the viewing distance showed differences for the lag of accommodation with greater lags at closer distances ($F_{4,80} = 7.280$, $p < 0.001$, $\eta_p^2 = 0.267$). The interaction *optical correction method x distance* did not yield statistical significance ($F_{4, 80} = 0.144$, $p = 0.965$). Post-hoc comparisons between both optical correction methods at the different viewing distances did not reach statistical significance after corrected with the Holm-Bonferroni procedure (all corrected p-values > 0.05) (Figure 1). Additionally, the association between refractive error and the differences in accommodative response between both optical correction methods was explored by linear regression analysis, showing that the Pearson correlation coefficients at the five viewing distances ranged between 0.17 and 0.33 (all p-values > 0.05). It should be noted that the limited range of refractive errors included in this study could mask a possible association of the differences in lags of accommodation between both optical correction methods and participants´ refractive error.

Variability of accommodative response differences

The standard deviation from the 30 sec dynamic accommodative response measure were used to define the variability of accommodation for the two optical correction methods (soft contact lenses and spectacles) at the five distances where the stimuli was presented. The mean value from both trials was considered. The optical correction method and the viewing distance exhibited statistical significance ($F_{1, 20} = 36.581$, $p < 0.001$, $\eta_p^2 = 0.647$; and $F_{4, 80} = 13.697$, $p < 0.001$, $\eta_p^2 = 0.406$, respectively), obtaining higher values of accommodative variability in the soft contact lenses condition and when viewing at closer distances. The interaction *optical correction method x distance* did not yield statistical significance ($F_{4, 80} = 1.287$, $p = 0.282$). Subsequently, we performed post-hoc analyses, obtaining statistically significant differences for the accommodative response variability between optical correction methods (higher variability with soft contact lenses) at the distances of 50 cm (corrected p-value = 0.005, effect size = 0.96), 40 cm (corrected p-value = 0.005, effect size = 1.06), 33 cm (corrected p-value = 0.010, effect size = 0.69), 25 cm (corrected p-value = 0.005, effect size = 0.88) and 20 cm (corrected p-value = 0.010, effect size = 0.69) (Figure 2). Lastly, the level of association between participant´s refractive error and the differences in the variability of accommodation between spectacles and soft contact lenses demonstrated to be low (Pearson correlation coefficient ranging from 0.04 to 0.30; all p-values > 0.05).

Inter-session repeatability

Table 2 shows the values of inter-session repeatability between the trial 1 and 2 for both optical correction methods (soft contact lenses and spectacles). The spectacles condition (Figure 3) and the soft contact lenses condition (Figure 4), as measured at all the tested distances, have proven to be strongly repeatable (Pearson and Intraclass correlation coefficient range: 0.95–0.99, and 0.94– 0.99, respectively) when measured two different days under the same experimental conditions. Please note that Bland-Altman plots for both spectacles conditions at 25 cm (Figure 3, panel D) and both soft contact lenses conditions at 33 cm (Figure 4, panel C) showed a significant association between the difference in measurements and the mean measurement, and thus, following the recommendations of Sedgwick[57], Bland-Altman plots were performed for the log transformed data. These analyses demonstrated that the associations between the difference in measurements and the mean measurement remained statistically significant in both analysed, which indicate a poor level of agreement.

Discussion

This study demonstrates that the use of soft contact lenses induces higher values of lag of accommodation (magnitude) and accommodative response fluctuations (variability) than spectacles under near work conditions (50, 40, 33, 25 and 20cm). Our results show that accommodative response measures, on two different occasions under the same experimental conditions, are highly repeatable for both correction methods (soft contact lenses and spectacles) and all the distances tested.

Magnitude of accommodative response

It is well known that a lag of accommodation higher than the depth of focus of an eye is associated with visual fatigue.[14,15,38] In the present study, higher lags of accommodation than 0.75 D, considered as a cut-off value for normative data in a non-clinical population,[40] were found at all near distances tested when wearing soft contact lenses (lag of accommodation of 1 D approximately). However, we found lags of accommodation lower than 0.75 D for all the viewing distances (from 50 to 20 cm) when wearing spectacles. A high lag of accommodation has been linked to accommodative and binocular anomalies such as accommodative insufficiency and convergence excess, which are frequently associated with ocular discomfort and strain at near.[38,40] Importantly, it should be considered that our data revealed lag of accommodation differences between both optical correction methods of about 0.30 D, and therefore, these differences may not be large enough to induce asthenopic symptoms. Also, the greater accommodative demand imposes by soft contact lenses in comparison to spectacles may play a role in the higher lags of accommodation found with soft contact lenses, however, the small range of refractive errors included in this study seems insufficient to explain these differences. Nevertheless, our findings agree, in part, with the accommodative response differences reported by Tosha et al.[15], who compared two groups with high and low visual discomfort (~0.40 D of difference at 20 cm between both groups). In addition, the accommodative response was recorded for a short time period (30 sec) in this study. We believe that wearing soft contact lenses during prolonged near activities may exacerbate asthenopic symptomatology in comparison to spectacles correction, in agreement with previous studies.[23,25] and it could be aggravated in prepresbyopic individuals.[58]

Numerous studies have focused on the genesis and aetiology of myopia progression, and the possible association between lag of accommodation and the onset of myopia. From an optical perspective, a continuous foveal hyperopic retinal blur due to a lag of accommodation has been considered as a possible cause for the development of myopia, but also it has been stated that accommodative lag may be a consequence rather than a cause of myopia.[16-18] Remarkably, the presence of correlation does not imply causation, and therefore, future studies are needed for the determination of causal directionality in the link of myopia progression and lag of accommodation. Our results evidenced that the accommodative response dynamically, objectively, and binocularly measured, was diminished with soft contact lenses when compared with spectacles. Nevertheless, future longitudinal studies including the assessment of central and peripheral defocus with spectacles versus soft contact lenses are needed to elucidate the role of optical correction method on the onset and progression of myopia.

Variability of accommodative response

The temporal characteristics of accommodation plays a role in accommodation control,[37] and in optical terms, high frequency fluctuations can impair image quality.[59] As with the lag of accommodation, high variability of accommodation promotes larger retinal defocus, and has also been linked to visual fatigue,[37,48] and myopia progression.[37,59,60] Our data demonstrate that wearing soft contact lenses induces a higher accommodation variability in near tasks and, therefore, these findings should be taken into account for optical correction prescription in relation to myopia progression and visual discomfort management. In agreement with the previous literature, the variability of accommodation is larger at closer viewing distances,[15,59] as it has been shown in the current study. Interestingly, we found a lower variability, although significant between both correction methods (see figure 2), at 40 cm distance. This length is considered as the habitual distance for near tasks in the vast majority of nonpresbyopic adults,[45,61] and it is also the normalized distance used in optometric examinations for near tests.[40] We support the contention that the visual functioning may be adapted to the habitually used distance in the real life. Future studies are required in this regard.

Lastly, as indicated by Harb, Thorn, & Troilo[62], those individuals who prefer closer reading distances may be more susceptible to develop myopia because both accommodative fluctuations and lags are greater. In this line, our data revealed higher values of accommodative variability and lag of accommodation with the use of soft contact lenses in comparison to spectacles, and it could further support the hypothesis that using soft contact lenses rather than spectacles during near tasks may exacerbate myopia progression.[63,64]

A plausible explanation for the present findings

There are several mechanisms that may explain our results. It should be noted that the study sample presents a trend toward to myopia (-0.79 [1.39] D), and recent evidence suggests that the vergence in myopes is slower, while the accommodation is less stable in comparison to emmetropes.[65] In addition, there is evidence about the influence of the optical correction method on the accommodative and vergence demands while viewing oscillatory targets, with myopes demonstrating greater accommodative and vergence requirements when wearing soft contact lenses in comparison to spectacles.[23] The use of soft contact lenses permit to maintain the optical centre in a correct position at all viewing distances (soft contact lens moves with the eye), whereas spectacle correction is normally centred at far distance and it is used for all viewing distances. In this regard, the use of spectacles by myopes and hyperopes, during near vision, induces base-in and base-out prism effects, respectively, and therefore, the vergence demands vary depending on the type of optical correction method and refractive error.[66] For example in the range of -3.25 to +2.75 D and considering a viewing distance of 20 cm, the prismatic effect ranges from 0.58 base-in to 0.50 base-out prismatic diopters. Additionally, it is well known that the retinal image size depends on the optical correction method due to its different distances in relation to the entrance pupil plane (approximately 15 mm in spectacles and 3mm in contact lenses). The magnification changes induced by lens powers of -4 D and +2 D, considering a base curve of +4 D and a refractive index of 1.5, are -0.24% and +1.23%, respectively.[40] Also, accommodative response is sensitive to lens effectivity, since accommodative demand changes as a consequence of the power of the refractive error.[67] However, theoretical calculations indicate that these difference are negligible when considering the average refractive error of our experimental sample (0.79 ± 1.39 D).[66] Consequently, the influence of retinal image size (magnification) and lens effectivity cannot completely explain the differences found for the accommodative response between spectacles and soft contact lenses. We consider that the inclusion of participants with larger refractive errors is needed to address this question. In this context, the eye obtains feedback from the fluctuations of accommodation (variability of accommodation) influencing the accommodative response,[68] and also, the fluctuations of accommodation are closely related to the error in the magnitude of accommodation.[37] Accordingly, some studies have found that there is a bi-directional relationship between the magnitude and variability of accommodation, which may exacerbate the differences found between both optical correction methods as consequence of the factors previously discussed (e.g., vergence demand, retinal image size). Although it was beyond to the aims of this study, we tested the possible association between the magnitude and variability of accommodative response when both wearing soft contact lenses and spectacles at the five distances tested, and we failed to find any statistically significant association (all p-values > 0.05) between both ocular parameters.[59,69] This lack of association may be due to the inclusion of different refractive groups, since the relationship between the magnitude and variability of accommodation has showed to be highly dependent on refractive group.[37,59] Lastly, the use of soft contact lenses promotes dry eye symptomatology, being blurry and changeable vision symptoms commonly reported by contact lens wearers.[70] Also, ocular dryness and poorer optical quality induced by soft contact lenses movement decrease optical quality,[71,72] which have showed a positive association with accommodative lag and fluctuations.[73] This possibility should be explored in future investigations.

Repeatability

The terms of repeatability and reproducibility refer to the precision in repeated measurement by one observer when all external factors are assumed constant, or when they (e.g., observer, instrument, environmental conditions, etc.) are altered, respectively. Here, we are considering the precision of measuring AR inter-sessions (repeatability) and inter-optical correction methods (reproducibility), and high levels of repeatability or reproducibility indicate that two measures are comparable and interchangeable.[54] For all the near stimuli (50, 40, 33, 25, and 20 cm), there were significant differences between optical correction methods (soft contact lenses induce a higher lag of accommodation), and thus, the accommodative response measure is incomparable between soft contact lenses and spectacles (see magnitude of accommodative response in the results section). Finally, our analysis yielded a strong inter-session repeatability at the five distances and both optical correction methods (Intraclass correlation coefficient range: 0.95-0.99), no variability exists between two measures of accommodative response when performed by the same observer, in the same experimental conditions, and with the same optical correction method.

Limitations and future research

The current study provides evidence on the modulation of accommodative response (magnitude and variability) as consequence of using soft contact lenses or spectacles with accommodative demands. The inter-sessions repeatability at all distances tested highlight that the objective measure of accommodative response with the instrument used in the present investigation is fairly repeatable, and demonstrate that a single measure under these conditions is enough to obtain valid results. In any case, the limits of agreement may be carefully considered, since no significant statistical differences may be of relevancy depending on the type of application (e.g., research, clinical, etc.). However, we think that several considerations may be taken into account in further research. Here, we adapted a soft contact lenses with a specific design and properties, and we would consider interesting to investigate the effects of other types of contact lenses (e.g. aspheric, bifocal, multifocal, defocus incorporated soft contact lenses, etc.), as well as testing the peripheral retinal defocus with different optical correction methods focusing on the influence in myopia progression.[74] It is our hope that future studies will explore the influence of wearing different optical correction methods considering different refractive groups, as well as during prolonged near tasks, with possible relevance in visual fatigue. Also, the refractive error range of our experimental sample was extremely limited, and thus, the non-existent association of the differences in the dynamics of ocular accommodation (magnitude and variability) between both optical correction methods and participants´ refractive error may be due to this fact. The inclusion of individuals with larger refractive errors are needed to test this possible relationship in future studies. Lastly, other factors such as cognitive demand, time of the day, the level of activation, and the level of visual symptomatology, including ocular dryness, may be considered due to its possible influence in the accommodative response.

Conclusions

The magnitude and variability of accommodative response are sensitive to the method used for ametropia correction, showing that soft contact lenses induce higher lags and larger fluctuations of ocular accommodation when compared with spectacles. These findings may have important implications in research (experimental designs) and clinical (emmetropization process and visual fatigue) contexts. Longitudinal studies are required to determine whether the differences in the accommodative response between optical correction methods affects to myopia progression. Further, experimental designs with prolonged near demands would show the effects on visual fatigue.

Funding: This study did not receive any type of funding support.

Conflict of Interest: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Acknowledgments: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. We thank the Servilens Fit & Covers Company (Granada, Spain) for the donation of the contact lens supplies used in this study.

References

1. Millodot M. Dictionary of Optometry and Visual Science. Dictionary of optometry and

visual science, 4th ed. Oxford: Butterworth-Heinemann; 1997.

2. Schor CM, Kotulak JC, Tsuetaki T. Adaptation of Tonic Accommodation Reduces Accommodative Lag and Is Masked in Darkness. Invest Ophthalmol Vis Sci 1986;27:820–7.

3. Green W, Ciuffreda KJ, Thiagarajan P, et al. Static and Dynamic Aspects of Accommodation in Mild Traumatic Brain Injury: A Review. Optometry 2010;81:129–36.

4. Adnan, EN, Mathur A, Edwards K, et al. Amplitude of Accommodation in Type 1 Diabetes. Invest Ophthalmol Vis Sci 2014;55:7014–8.

5. Dick AD, Tundia N, Sorg R, et al. Risk of Ocular Complications in Patients with Noninfectious Intermediate Uveitis, Posterior Uveitis, or Panuveitis. Ophthalmology 2016;123:655–62.

6. Santaella R, Fraufelder F. Ocular Adverse Effects Associated with Systemic Medications: Recognition and Management. Drugs 2007;67:75–93.

7. Miguel A, Henriques F, Azevedo L, Costa Pereira A. Ophthalmic Adverse Drug Reactions to Systemic Drugs: A Systematic Review. Pharmacoepidemiol Drug Saf 2014;23:221–3.

8. McClelland JF, Parkes J, Hill N,et al. Accommodative Dysfunction in Children with Cerebral Palsy: A Population-Based Study. Invest Opthalmol Vis Sci 2006;47:1824.

9. Culhane HM, Winn B. Dynamic Accommodation and Myopia. Invest Ophthalmol Vis Sci 1999;40:1968–74.

10. Manh V, Chen AM, Tarczy-Hornoch K, et al. Accommodative performance of children with unilateral amblyopia. Invest Ophthalmol Vis Sci 2015;56:1193–207.

11. García-Muñoz Á, Carbonell-Bonete S, Cantó-Cerdán M, Cacho-Martínez P. Accommodative and Binocular Dysfunctions: Prevalence in a Randomised Sample of

University Students. Clin Exp Optom 2016;99:313–21.

12. Wang B, Ciuffreda KJ. Depth-of-Focus of the Human Eye in the Near Retinal Periphery. Vision Res 2004;44:1115–25.

13. Bernal-Molina P, Montés-Micó R, Legras R, López-Gil N. Depth-of-Field of the Accommodating Eye. Optom Vis Sci 2014;91:1208–14.

14. Chase C, Tosha C, Borsting E, Ridder W. Visual Discomfort and Objective Measures of Static Accommodation. Optom Vis Sci 2009;86:883–9.

15. Tosha C, Borsting E, Ridder WH, Chase C. Accommodation Response and Visual Discomfort. Ophthalmic Physiol Opt 2009;29:625–33.

16. Gwiazda J, Thorn F, Held R. Accommodation, Accommodative Convergence, and Response AC/A Ratios before and at the Onset of Myopia in Children. Optom Vis Sci 2005;82:273–8.

17. Mutti DO, Mitchell GL, Hayes JR, et al. Accommodative Lag before and after the Onset of Myopia. Invest Ophthalmol Vis Sci 2006;47:837–46.

18. Millodot M. The Effect of Refractive Error on the Accommodative Response Gradient: A Summary and Update. Ophthalmic Physiol Opt 2015;35:607–12.

19. Koomson N, Amedo A, Opoku-Baah C, et al. Relationship between Reduced Accommodative Lag and Myopia Progression. Optom Vis Sci 2016;93.

20. Wolffsohn JS, Calossi A, Cho P, et al. Global Trends in Myopia Management Attitudes and Strategies in Clinical Practice. Cont Lens Anterior Eye 2016;39:106–16.

21. Berntsen DA, Sinnott LT, Mutti DO, Zadnik K. Accommodative Lag and Juvenile-Onset Myopia Progression in Children Wearing Refractive Correction. Vision Res 2011;51:1039–46.

22. Alpern M. Accommodation and Convergence with Contact Lenses. Optom Vis Sci

1949;26:379–87.

23. Hunt OA, Wolffsohn JS, García-Resúa C. Ocular Motor Triad with Single Vision Contact Lenses Compared to Spectacle Lenses. Cont Lens Anterior Eye 2006;29:239–45.

24. Bennett ES, Weissman BA. Clinical Contact Lens Practice. Lippincott Williams & Wilkins; 2005.

25. Jiménez R, Martínez-Almeida L, Salas C, Ortíz C. Contact Lenses vs Spectacles in Myopes: Is There any Difference in Accommodative and Binocular Function? Graefe's Arch Clin Exp Ophthalmol 2011;249:925–35.

26. Kanonidou E, Chatziralli IP, Konidaris V, et al. A Comparative Study of Visual Function of Young Myopic Adults Wearing Contact Lenses vs. Spectacles. Cont Lens Anterior Eye 2012;35:196–8.

27. Ehsaei A, Chisholm CM, MacIsaac JC, et al. Central and Peripheral Visual Performance in Myopes: Contact Lenses versus Spectacles. Cont Lens Anterior Eye 2011;34:128–32.

28. Pascal JI. Scope and Significance of the Accommodative Unit. Optom Vis Sci 1952;29:113–28.

29. Locke, LC. A Comparison Study of Dynamic Retinoscopy. Optom Vis Sci 1989;66:540–4.

30. Cacho, MP, García-Muñoz A, García-Bernabeu JR, López A. Comparison between MEM and Nott Dynamic Retinoscopy. Optom Vis Sci 1999;76:650–5.

31. García Á, Cacho P. MEM and Nott Dynamic Retinoscopy in Patients with Disorders of Vergence and Accommodation. Ophthalmic Physiol Opt 2002;22:214–20.

32. McClelland JF, Saunders KJ. The Repeatability and Validity of Dynamic Retinoscopy in Assessing the Accommodative Response. Ophthalmic Physiol Opt 2003;23:243–50.

33. Antona B, Sanchez I, Barrio A, et al. Intra-examiner Repeatability and Agreement in Accommodative Response Measurements. Ophthalmic Physiol Opt 2009;29:606–14.

34. Win-Hall DM, Houser J, Glasser A. Static and Dynamic Measurement of Accommodation Using the Grand Seiko WAM-5500 Autorefractor. Optom Vis Sci 2010;87.

35. Sheppard AL, Davies LN. Clinical Evaluation of the Grand Seiko Auto Ref/Keratometer WAM-5500. Ophthalmic Physiol Opt 2010;30:143–51.

36. Aldaba M, Gómez-López S, Vilaseca M, et al. Comparing Autorefractors for Measurement of Accommodation. Optom Vis Sci 2015;92.

37. Charman WN, Heron G. Microfluctuations in Accommodation: An Update on their Characteristics and Possible Role. Ophthalmic Physiol Opt 2015;35:476–99.

38. Thiagarajan P, Ciuffreda KJ. Visual Fatigue and Accommodative Dynamics in Asymptomatic Individuals. Optom Vis Sci 2013;90:57–65.

39. Conlon EG, Lovegrove WJ, Chekaluk E, Pattison PE. Measuring Visual Discomfort. Vis cogn 1999;6:637–63.

40. Scheiman M, Wick B. Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders. Lippincott Williams & Wilkins; 2008.

41. Hoddes E, Zarcone V, Dement W. Development and Use of Stanford Sleepiness Scale (SSS). Psychophysiology 1972;9:150.

42. Gould G. A method of Determining Ocular Dominance. JAMA 1910;55.

43. Oliveira S, Jorge J, González-Méijome JM. Dynamic Accommodative Response to Different Visual Stimuli (2D vs 3D) while Watching Television and while Playing Nintendo 3DS Console. Ophthalmic Physiol Opt 2012;32:383–9.

44. Nemeth G, Lipecz A, Szalai E, et al. Accommodation in Phakic and Pseudophakic Eyes

Measured with Subjective and Objective Methods. J Cataract Refract Surg 2013;39:1534–42.

45. Roberts, TL, Anderson, HA, Stuebing, KK. Accommodative Gain in Relation to Perceived Target Clarity. Optom Vis Sci 2015;92.

46. Momeni-Moghaddam H, McAlinden C, Azimi A, et al. Comparing Accommodative Function between the Dominant and Non-Dominant Eye. Graefe's Arch Clin Exp Ophthalmol 2014;252:509–14.

47. Di Stasi LL, McCamy MB, Catena A, et al. Microsaccade and Drift Dynamics Reflect Mental Fatigue. Eur J Neurosci 2013;38:2389–98.

48. Lin W, Lin M, Chen Y, Chen H. Effects of Near Addition Lenses and Prisms. Optom Vis Sci 2016;93:488–96.

49. Vera J, Diaz-Piedra C, Jiménez R, et al. Driving Time Modulates Accommodative Response and Intraocular Pressure. Physiol Behav 2016;164:47–53.

50. Poltavski DV., Biberdorf D, Petros TV. Accommodative Response and Cortical Activity During Sustained Attention. Vision Res 2012;63:1–8.

51. Atchison DA, Varnas SR. Accommodation Stimulus and Response Determinations with Autorefractors. Ophthalmic Physiol Opt 2017;37:96–104.

52. Holm S. A Simple Sequentially Rejective Multiple Test Procedure. Scand J Stat 1979;6:65–70.

53. Armstrong RA. When to Use the Bonferroni Correction. Ophthalmic Physiol Opt 2014;34:502–8.

54. McAlinden C, Khadka J, Pesudovs K. Statistical Methods for Conducting Agreement (Comparison of Clinical Tests) and Precision (Repeatability or Reproducibility) Studies in Pptometry and Ophthalmology. Ophthalmic Physiol Opt 2011;31:330–8.

55. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. Med Sci Sports Exerc 2009;41:3–12.

56. Martin Bland J, Altman D. Statistical Methods for Assessing Agreement Between Two Methods of Clinical Measurement. Lancet 1986;327:307–10.

57. Sedgwick P. Limits of Agreement (Bland-Altman method). BMJ 2013;346:1–2.

58. Anderson HA, Glasser A, Manny RE, Stuebing KK. Age-related Changes in Accommodative Dynamics from Preschool to Adulthood. Invest Ophthalmol Vis Sci 2010;51:614–22.

59. Langaas T, Riddell PM, Svarverud E, et al. Variability of the Accommodation Response in Early Onset Myopia. Optom Vis Sci 2008;85:37–48.

60. Wallman J, Winawer J. Homeostasis of Eye Growth and the Question of Myopia. Neuron 2004;43:447–68.

61. Rah MJ, Mitchell GL. Prospective Quantification of Near Work Using the Experience Sampling Method. Optom Vis Sci 2001;78:496–502.

62. Harb E, Thorn F, Troilo D. Characteristics of Accommodative Behavior during Sustained Reading in Emmetropes and Myopes. Vision Res 2006;46:2581–92.

63. Wu LJ, You QS, Duan JL, et al. Prevalence and Associated Factors of Myopia in High-School Students in Beijing. PLoS One 2015;10:1–12.

64. Li SM, Li SY, Kang MT, et al. Near Work Related Parameters and Myopia in Chinese Children: The Anyang Childhood Eye Study. PLoS One 2015;10:1–13.

65. Maiello G, Kerber KL, Thorn F, et al. Vergence Driven Accommodation with Simulated Disparity in Myopia and Emmetropia. Exp Eye Res 2017;166:96–105.

66. Phillips AJ, Stone J. Contact Lenses: A Textbook for Practitioner and Student. Philadelphia: Butterworth-Heinemann; 1989.

67. Fannin TE, Grosvenor T. Clinical Optics. Philadelphia: Butterworth-Heinemann; 2013.

68. Toates FM. Accommodation Function of the Human Eye. Physiol Rev 1972;52:828–63.

69. Sreenivasan V, Irving EL, Bobier WR. Effect of Near Adds on the Variability of Accommodative Response in Myopic Children. Ophthalmic Physiol Opt 2011;31:145–54.

70. Begley CG, Caffery B, Nichols KK, Chalmers R. Responses of Contact Lens Wearers to a Dry Eye Survey. Optom Vis Sci 2000;77:40–6.

71. Montés-Micó R. Role of the Tear Film in the Optical Quality of the Human Eye. J Cataract Refract Surg 2007;33:1631–5.

72. Watanabe RK, Ridder WH, Tomlinson A. Visual Performance of Three Disposable Soft Contact Lenses. Int Contact Lens Clin 1993;20:106–12.

73. Gambra E, Sawides L, Dorronsoro C, Marcos S. Accommodative Lag and Fluctuations when Optical Aberrations are Manipulated. J Vis 2009;9:1–15.

74. Berntsen DA, Kramen CE. Peripheral Defocus with Spherical and Multifocal Soft Contact Lenses. Optom Vis Sci 2013;90:1215–24.

Figure captions

Figure 1. Effects of optical correction method (soft contact lenses versus spectacles) on the lag of accommodation. Average lag of accommodation for each distance with both methods of correction. Data from the spectacles correction are represented with green triangles and, from the soft contact lenses with blue squares. The lag of accommodation values correspond to the average value from both trials with each optical correction method. Error bars show the Standard Deviation (SD).

Figure 2. Effects of optical correction method (soft contact lenses versus spectacles) on the accommodative response variability. Mean standard deviation of accommodative response for each distance with both methods of optical correction. Data from the spectacles correction are represented with green triangles and, from the soft contact lenses with blue squares. The accommodative response variability values correspond to the average value from both trials with each optical correction method. * indicates statistically significant differences between both optical correction methods at each specific accommodative (corrected p-values < 0.05). Error bars show the Standard Deviation (SD).

Figure 3. Bland and Altman plots illustrating the intersession repeatability of accommodative response measurements (lag of accommodation) made in participants while wearing spectacles correction at 50 cm (A), 40 cm (B), 33 cm (C), 25 cm (D), and 20 cm (E). The x-axis shows the mean lag of accommodation from trial 1 and trial 2. The dotted line represents the mean bias and the dashed lines show the 95% limits of agreement. The regression line is represented by a solid black line, and the grey lines indicate the value zero.

Figure 4. Bland and Altman plots illustrating the intersession repeatability of accommodative response measurements (lag of accommodation) made in participants while wearing soft contact lenses correction at 50 cm (A), 40 cm (B), 33 cm (C), 25 cm (D), and 20 cm (E). The x-axis shows the mean lag of accommodation from trial 1 and trial 2. The dotted line represents the

mean bias and the dashed lines show the 95% limits of agreement. The regression line is represented by a solid black line, and the grey lines indicate the value zero.

Table 1

Table 1. Inclusion criteria and sample values of the visual parameters evaluated.

	Inclusion criteria values	Study sample values (mean ± SD, range)
Visual symptomatology		
Conlon questionnaire	< 24 (low discomfort)	6.18 ± 3.16, 1 - 14
Visual acuity		
Right eye (logMAR)	≤ 0.00 log MAR	-0.08 ± 0.03, -0.14 – 0 log MAR
Left eye (logMAR)	≤ 0.00 log MAR	-0.07 ± 0.03, -0.13 – 0 log MAR
Refractive error		
Spherical component (D)	between -5.00D and +3.00D	-0.79 ± 1.39, -3.25 - +2.75 D
Astigmatic component (D)	< 2.00D	0.68 ± 0.30, 1.50 – 0 D
Accommodative testing		
Amplitude of accommodation (D)	18 – 1/3 age ± 2D	11.81 ± 1.47, 10 – 13 D
Monocular accommodative facility (cpm, RE)	11 ± 5 cpm	10.84 ± 3.14, 8 – 14 cpm
Monocular accommodative facility (cpm, LE)	11 ± 5 cpm	10.45 ± 2.84, 8 – 14 cpm
Binocular accommodative facility (cpm)	10 ± 5 cpm	10.42 ± 2.12, 8 – 13 cpm
Binocular testing		
Distance phoria (Δ)	1 exophoria ± 2 Δ	0.85 exophoria ± 1.20, 1 esophoria – 2 exophoria Δ
Near phoria (Δ)	3 exophoria ± 3 Δ	1.45 exophoria ± 1.05, 1 exophoria – 5 exophoria Δ
Distance negative fusional vergence (Δ, break/recovery)	7 ± 3 Δ / 4 ± 2 Δ	8.45 ± 1.85/ 4.40 ± 1.50, 5 – 9/ 3 – 5 Δ
Distance positive fusional vergence (Δ, break/recovery)	11 ± 7 Δ / 7 ± 2 Δ	13.65 ± 3.68 / 8.05 ± 1.40, 10 – 17/ 6 – 9 Δ
Near negative fusional vergence (Δ, break/recovery)	13 ± 6 Δ / 10 ± 5 Δ	15.40 ± 4.20 / 11.53 ± 3.42, 10 – 19/ 8 – 15 Δ
Near positive fusional vergence (Δ, break/recovery)	19 ± 9 Δ / 14 ± 7 Δ	22.26 ± 6.24 / 16.07 ± 4.21, 17 – 27/ 12 – 21 Δ
Near point of convergence (cm, break/recovery)	5 ± 2.5 cm/ 7 ± 3 cm	5.85 ± 1.74 / 7.72 ± 2.05, 4 – 7/ 5 – 9 cm

Note: Amplitude of accommodative was measured by the push-up technique using an accommodative target, monocular and binocular accommodative facility was measured with ± 2.0 diopters flippers, distance and near phorias were measured by Thorington's method, vergences were measured by prisms bar, and the near point of convergence was measured by the push-up technique using an accommodative target. Accommodation and vergence values correspond to those given by Scheiman & Wick (2008).[40]

Abbreviations: logMAR = logarithm of the Minimum Angle of Resolution, D = diopters, cpm = cycles per minute, Δ= prismatic dioptre, RE = right eye, LE = left eye, cm = centimetre.

Table 2

Table 2. Inter-session repeatability between trial 1 and 2 for both optical correction methods at the six distances tested.

	p-value	ES	r	ICC
SCL 50 cm	0.81	0.01	0.98	0.98
Spectacles 50 cm	0.20	0.05	0.99	0.99
SCL 40 cm	0.47	0.03	0.98	0.98
Spectacles 40 cm	0.66	0.02	0.99	0.99
SCL 33 cm	0.87	0.01	0.99	0.99
Spectacles 33 cm	0.60	0.02	0.99	0.99
SCL 25 cm	0.69	0.03	0.95	0.94
Spectacles 25 cm	0.36	0.03	0.99	0.99
SCL 20 cm	0.02	0.13	0.98	0.98
Spectacles 20 cm	0.23	0.06	0.98	0.98

Abbreviations: SCL = soft contact lens; ES = effect size; r = Pearson coefficient of correlation; ICC = Intraclass correlation coefficient; m = meters; cm = centimeters.

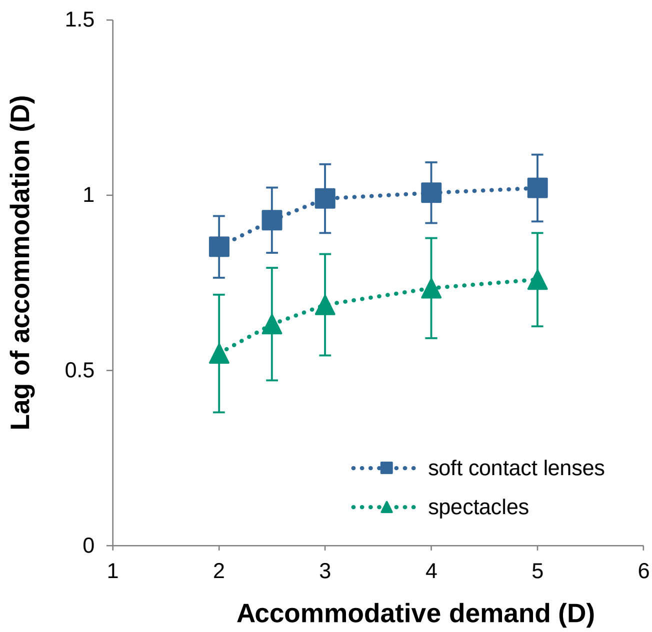
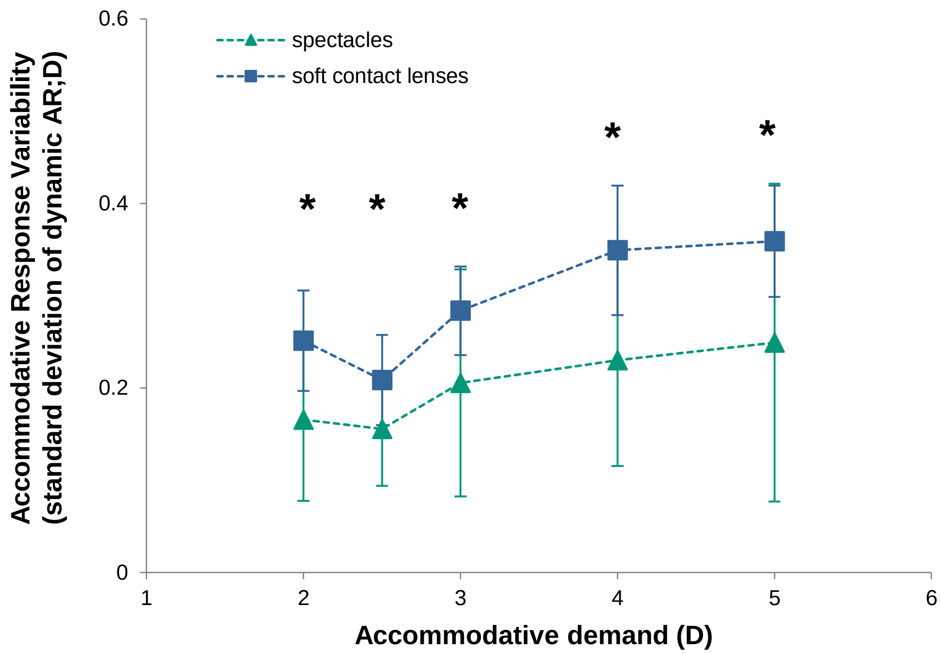

1.5
1
0.5
0
Lag of accommodation (D)
1
2
3
4
5
6
Accommodative demand (D)
soft contact lenses
spectacles

Figure 1



Accommodative Response Variability
(standard deviation of dynamic AR;D)
0.6
0.4
0.2
0
spectacles
soft contact lenses
*
*
*
*
*
1
2
3
4
5
6
Accommodative demand (D)

Figure 2

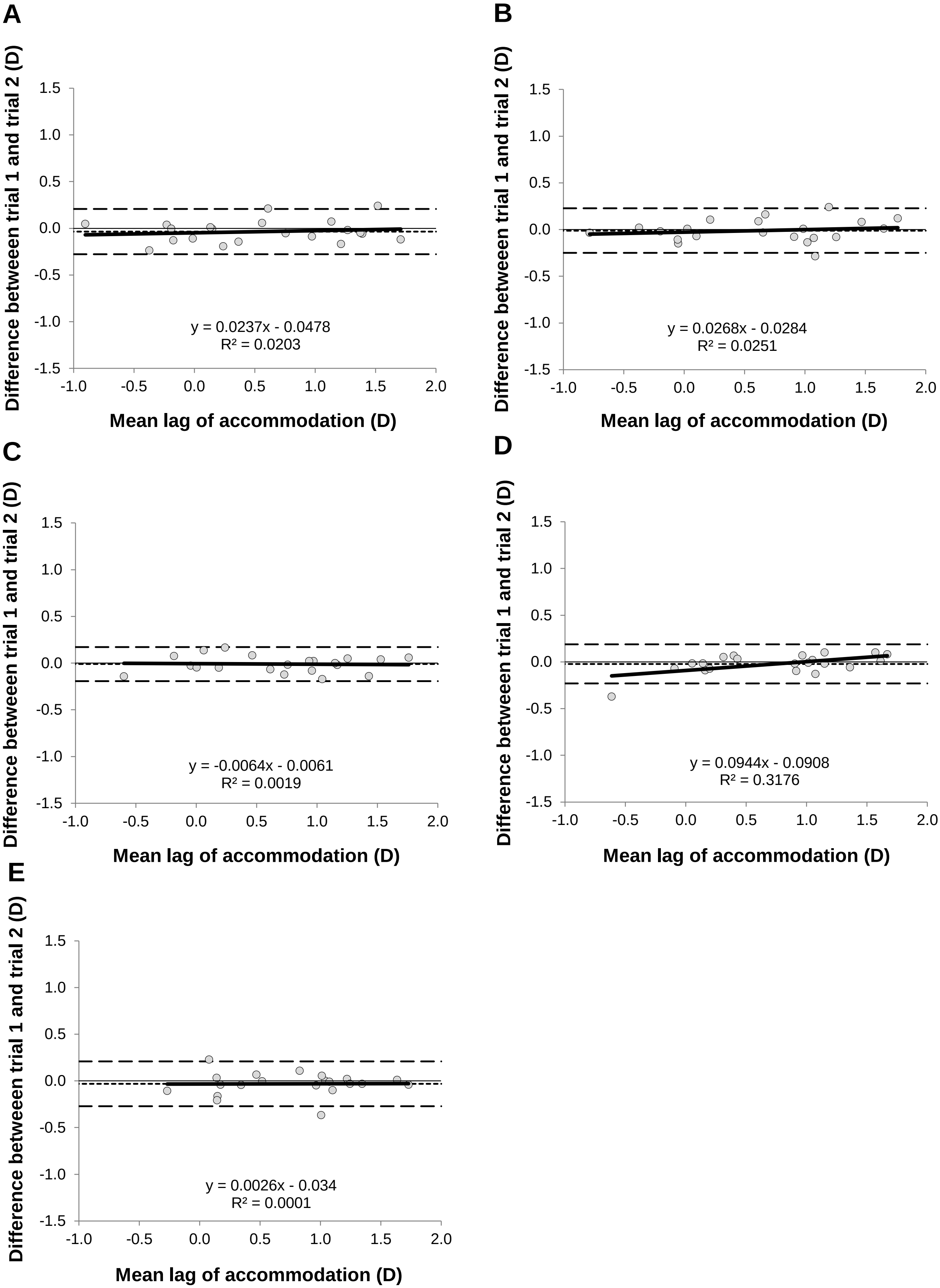

A
Difference betweeen trial 1 and trial 2 (D)
Mean lag of accommodation (D)
y = 0.0237x - 0.0478
R² = 0.0203
B
Difference betweeen trial 1 and trial 2 (D)
Mean lag of accommodation (D)
y = 0.0268x - 0.0284
R² = 0.0251
C
Difference betweeen trial 1 and trial 2 (D)
Mean lag of accommodation (D)
y = -0.0064x - 0.0061
R² = 0.0019
D
Difference betweeen trial 1 and trial 2 (D)
Mean lag of accommodation (D)
y = 0.0944x - 0.0908
R² = 0.3176
E
Difference betweeen trial 1 and trial 2 (D)
Mean lag of accommodation (D)
y = 0.0026x - 0.034
R² = 0.0001

Figure 3

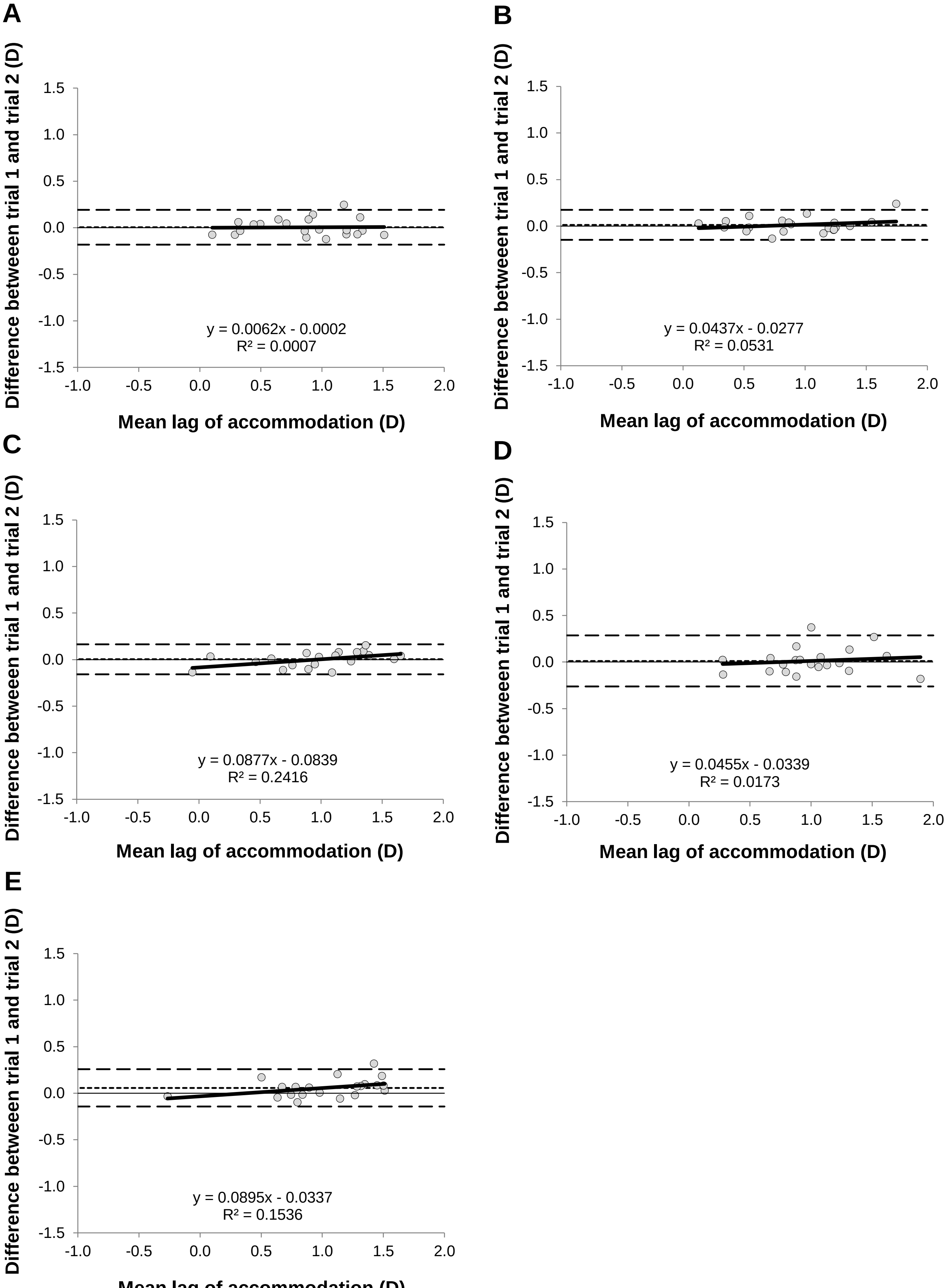

A
Difference betweeen trial 1 and trial 2 (D)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
y = 0.0062x - 0.0002
R² = 0.0007
Mean lag of accommodation (D)
B
Difference betweeen trial 1 and trial 2 (D)
y = 0.0437x - 0.0277
R² = 0.0531
Mean lag of accommodation (D)
C
Difference betweeen trial 1 and trial 2 (D)
y = 0.0877x - 0.0839
R² = 0.2416
Mean lag of accommodation (D)
D
Difference betweeen trial 1 and trial 2 (D)
y = 0.0455x - 0.0339
R² = 0.0173
Mean lag of accommodation (D)
E
Difference betweeen trial 1 and trial 2 (D)
y = 0.0895x - 0.0337
R² = 0.1536
Mean lag of accommodation (D)

Figure 4