IL NUOVO CIMENTO **47 C** (2024) 331
DOI 10.1393/ncc/i2024-24331-5

Communications: SIF Congress 2023

The influence of ametropia on pupil diameter

P. A. Grasso(1)(2), F. Tommasi(1)(2), D. Kardatos(3), M. Gurioli(1)(2) and L. Boccardo(2)(3)

(1) *Dipartimento di Fisica e Astronomia - Via G. Sansone 1, 50019 Sesto Fiorentino, Italy*
(2) *Università di Firenze, Corso di Laurea in Ottica e Optometria - Firenze, Italy*
(3) *IRSOO Istituto Ricerca e Studi in Ottica e Optometria - Piazza della Libertà 18, 50059 Vinci, Italy*

received 10 April 2024

Summary. — The pupil changes its size in response to a series of factors among which the most relevant one is variations in the level of environmental brightness. Some studies proposed that pupil diameter can also be affected by refractive condition although no consensus has been reached on this topic as other intervening factors could also explain such trend.Here we used a causal approach to tackle this point. We measured pupil diameters in a group of myopes and a group of hyperopes in two separate conditions. A condition where participants did not wear any correction (NC condition) and a condition in which their ametropia was corrected by means of daily disposable contact lenses matching their individual spherical equivalent (CL condition). In both conditions, pupil diameter was assessed at three distinct light levels (photopic, mesopic and scotopic). Results revealed a significant difference in pupil diameter between hyperopes and myopes in the NC condition at all the three light levels. Nevertheless, this difference was robustly reduced in the CL condition suggesting a causal relationship between ametropia and pupil size.

1. – Introduction

Pupil responds to variation in the incoming light by dynamically changing its diameter. This automatic behavior is mediated by the parasympathetic and the sympathetic parts of the autonomous nervous system and is crucial to control retinal illumination and to adjust depth of focus [1].

Apart from response to incoming light, pupil diameter is known to get modulated by a plethora of factors. For instance, it is well documented that steady-state baseline pupil diameter progressively decreases with age with elderly people also showing reduced pupil dynamics in response to incoming light [2, 3]. More recently, pupil size has also been linked to high-level visual processing, including attention, mental imagery, and contextual modulation demonstrating that the pupil diameter is not solely determined by physiological factors [4, 5]. Another crucial aspect being sometimes associated with changes in pupil size is baseline refractive condition. This association is mostly related to the accommodative triad, a three-component mechanism occurring whenever the eyes focus on object up close. The eyes converge, the lenses in eyes increase in thickness, leading to a consequent increase in optical power, and the pupil diameter decreases. This accommodative response is a reflex that assists in the redirection of gaze from a distant to a nearby object [6]. Uncorrected young hyperopes are known to continuously implement accommodative behaviors also during far vision. This practice is thought to be the cause of the reduced pupil diameter being sometimes reported in the hyperopic population as compared to both emmetropes and myopes. Nevertheless, it is important to point out that the relationship between refractive status and pupil diameter produced equivocal findings. Indeed, while some studies found a significant relation with refractive error [7-9], others did not [10-12]. One possible interpretation for the discrepancies reported across different studies could be related to the influence of confounding factors such as age. As the prevalence of myopia, emmetropia, and hyperopia differs substantially depending on age groups and this could produce important variation in the final result [2, 9].

Given that this point is strongly debated in the scientific literature, we used here a causal approach to reduce the influence of other factor that may have influenced previous findings. On the one hand, we selected a very specific age group within the young age population. On the other hand, the influence of refractive status on pupil diameter was investigated in a within subject design. More, specifically, all the recruited participants underwent two measurements which were performed under a condition of uncorrected ametropia and a condition where their initial ametropia was corrected with use of daily disposable contact lenses.

2. – Materials and methods

2·1. *Participants.* – A total of 22 participants (10 males and 12 females; mean age: 23.5 years; std: 2.8 years; age range: 20 to 31) took part in the study. All participants had corrected distance visual acuity equal or greater than 0.00 LogMAR. The research was conducted in accordance with the Declaration of Helsinki.

2·2. *Procedure and data collection.* – Pupil diameter was assessed by an optical topographer (Sirius, CSO, Italy) performing measurements with the help of an inbuilt infrared camera. Measurements were conducted under scotopic (0.04 lux), mesopic (4 lux) and photopic (40 lux) light conditions. Pupil diameters within the three light conditions were assessed twice. First with participants wearing no correction (NC condition) and afterwards with participants wearing daily disposable contact lenses matching their individual spherical equivalent (CL condition). Individual spherical equivalent was assessed by an expert optometrist by means of a retinoscopy.

2·3. *Statistical Analysis.* – We performed statistical analyses using ANOVAs or two-tailed independent sample t-tests (using JASP, Version 0.14.1.0). Post-hoc comparisons were adjusted using the Bonferroni correction.

3. – Results

The sample of participants was split into two subgroups based on spherical equivalent. This procedure led to the selection of 10 myopes (5 males and 5 females; mean age: 23.3 years; std: 2.3 years; age range: 20 to 27; average spherical equivalent: -4.4 D; std: 2.1 D; range: -2.25 to -9.37 D; average cylinder: -1.01 D: std: 1.04 D; range: 0 to -3.75 D) and 12 hyperopes (5 males and 7 females; mean age: 23.8 years; std: 3.3 years; age range: 20 to 31; average spherical equivalent: 2.4 D; std: 0.8 D; range: 1.5 to 4 D; average cylinder: -0.29 D: std: 0.3 D; range: 0 to -1 D). No difference in age emerged between the two groups ($t(20) = 0.368; p = 0.71$).

First, we conducted a 3×2 mixed ANOVA with the within factor Light (photopic, mesopic, scotopic) and the between factor Group (myopes, hyperopes) to check for any specificity of the effect of light in the two groups of participants in the NC condition. As expected, the analysis revealed a highly significant main effect of Light ($F(2,40) = 174.120; p < 0.001; \eta^2 = 0.55$) explained by decreased pupil diameters as a function of an increase in light ($photopic : 4.1\,\text{mm}; mesopic : 5.3\,\text{mm}; scotopic : 6.7\,\text{mm}; allp < 0.001$). Interestingly also a main effect of Group emerged ($F(1,20) = 22.46; p < 0.001; \eta^2 = 0.20$) which highlighted larger pupil sizes in the group of myopes (mean: 6.1 cm) as compared to the group of hyperopes ($mean : 4.8\,\text{cm}; p < 0.001$). No interaction between the two factors was evident ($F(2,40) = 1.41; p = 0.256$) suggesting that hyperopes and myopes shared similar pupil dynamics with respect to light changes.

The same mixed ANOVA with the within factor light (photopic, mesopic, scotopic) and the between factor Group (myopes, hyperopes) was conducted for the CL condition. As expected, results still revealed a highly significant main effect of Light ($F(2,40) = 159.256; p < 0.001;\ \eta^2 = 0.66$) once again explained by decreased pupil diameters as a function of an increase in light ($photopic : 4.3\,\text{mm}; mesopic : 5.6\,\text{mm}; scotopic : 6.7\,\text{mm}; allp < 0.001$). Interestingly, in this case neither the main effect of Group ($F(1,20) = 3.896; p = 0.06; \eta^2 = 0.04$) nor the interaction Light x Group ($F(2,40) = 1.369; p = 0.266; \eta^2 = 0.006$) reached significance suggesting that in the CL condition the pupil diameters between the two groups were way closer than in the NC condition (fig. 1).

Finally, an ANOVA with the within factor light (photopic, mesopic, scotopic) and the between factor Group (myopes, hyperopes) was conducted on absolute differences in pupil size between the CL and the NC condition. This analysis aimed at testing whether changes in pupil diameters between CL and NC conditions were more pronounced in one of the two groups. No main effect of Group emerged ($F(1,20) = 0.896; p = 0.357; \eta^2 = 0.016$) suggesting that the absolute variation in pupil diameter between the two groups was not statistically significant.

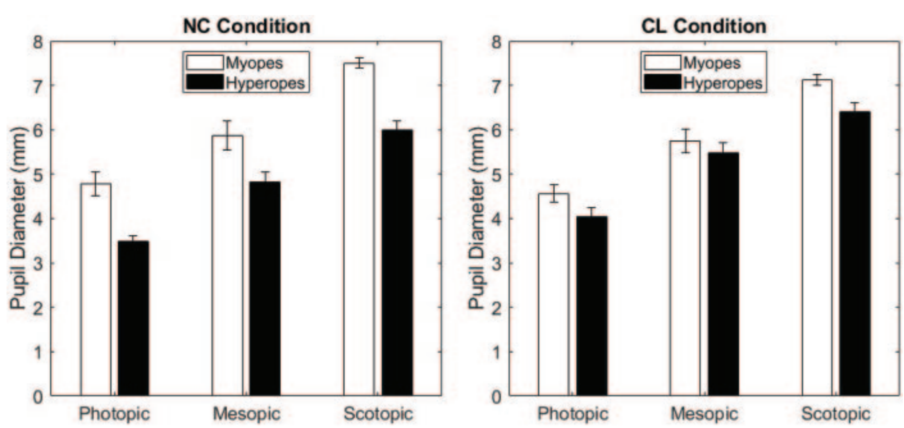

Fig. 1. – Pupil diameters measured in the condition of no correction (NC condition) and in the condition of participants wearing daily disposable contact lenses matching their individual spherical equivalent (CL condition). White bars depict myopes and black bars depict hyperopes. Error bars represent SEM.

4. – Conclusions

In the current study we used a causal approach to investigate the relationship between pupil diameter and refractive condition. We recruited two groups of participants with different ametropic conditions. A group of myopes and a group of hyperopes. The two groups were matched in age and performed two pupil measurements under a condition of no correction and a condition where ametropia was corrected by means of daily disposable contact lenses. While in the NC condition the two groups were characterized by a significant difference in pupil size evident at all the three light levels administered, this was not the case for the CL condition where the two groups of myopes and hyperopes did not differ anymore in pupil diameter. Importantly, the current study allowed to exclude the impact of potential physiological factors known to exert a role in pupil diameter. First, we selected two groups that were matched in age. This characteristic allowed us to exclude the possibility that differences in pupil diameters measured between the two ametropic groups could be mainly due to differences in age [2, 9]. Second, we used here a within-subjects design which allowed us to explore whether differences in pupil diameters are causally linked to the initial ametropic condition. Our results not only confirmed that hyperopes had smaller pupil diameters [7-9] as compared to an age-matched group of myopes, but also that this difference was way reduced when their refractive error was corrected. We showed that the small pupil sizes generally measured in uncorrected hyperopes may be due to the accommodative response carried out to compensate ametropia. Similarly, myopes showed a pattern of reduced pupil diameters when wearing contact lenses, a result likely due to proximally-induced accommodation behaviours, confirming that measures of pupil size in the young population are mostly related to the accommodative response.

In conclusion, our data report evidence of an association between refractive condition and pupil diameter. Although we acknowledge that the sample size was relatively small, we believe that the use of a causal approach and a restricted age range allowed us to exclude other intervening factors providing good evidence for the importance of correcting ametropia when comparing pupil diameters across different groups.

* * *

The study was conducted with the contribution of the researcher Paolo Antonino Grasso with a research contract co-funded by the European Union - PON Research and Innovation 2014–2020 in accordance with Article 24, paragraph 3a, of Law No. 240 of 30 December 2010, as amended, and Ministerial Decree No. 1062 of 10 August 2021.

REFERENCES

[1] Zele A. J. and Gamlin P. D., *Front Neurol*, **11** (2020) 211.
[2] Diamond J. P., *Br. J. Ophtalmol.*, **85** (2001) 121.
[3] Ellis C. J. K., *Br. J. Ophtalmol.*, **65** (1981) 754.
[4] Binda P. and Murray S.O., *Trends Cong. Sci.*, **19** (2015) 1.
[5] Mathôt S. and Van der Stigchel S., *Curr. Dir. Psychol. Sci.*, **24** (2015) 374.
[6] Emslie R., Sachs N., Claassens A. and Walters I., *Afri. Vis. Eye Health*, **66** (2007) 184.
[7] Cakmak H. B., Cagil N., Simavli H., Duzen B. and Simsek S., *Curr. Eye. Res.*, **35** (2010) 130.

[8] Guillon M., Dumbleton K., Theodoratos P., Gobbe M., Wooley C. B. and Moody, K., *Optom. Vis. Sci.*, **93** (2016) 1093.
[9] Lee Y. S., Kim H. J., Lim D. K., Kim M. H. and Lee, K. J., *Medicine*, **101** (2022) e29864.
[10] Jones R., *Investig. Ophtalmol. Vis. Sci.*, **31** (1990) 1413.
[11] Orr J. B., Seidel D., Day M. and Gray L. S., *Optom. Vis. Sci.*, **92** (2015) 834.
[12] Winn B., Whitaker D., Elliott D. B. and Phillips N. J., *Investig. Ophtalmol. Vis. Sci.*, **35** (1994) 1132.