Author Response: Systematic Imaging Experiments of Accommodation Do Not Require Image Registration

We are writing in response to Dr. Schachar's letter[1] regarding our two recently published studies.[2,3] The issue raised by Dr. Schachar is misleading, as he uses a portion of a figure that was designed primarily to show the results of our contrast agent experiments in the second study[3] and not how we collected measurements; the latter was addressed in the first study.[2]

The panels we selected for the figure that Dr. Schachar mentions (left and middle panels of Fig. 1) were chosen to show the extent of how the triesence particles cling to the vitreous membrane, that the anterior hyaloid bows backward during accommodation, and that the cleft between the pars plicata and the anterior hyaloid decreases with age. The idea that the length of the cornea in the image, and thereby the position of the ultrasound biomicroscopy (UBM) probe with respect to the eye, could account for the magnitude of the accommodative response or aging change is not correct (see Supplementary Videos S1–S8 of our paper that studies the accommodative movements of the vitreous).[3] The figure portion that Dr. Schachar reproduced in his letter simply shows that, despite some variability of the anterior/posterior position of the UBM probe in relation to the eye, the results were the same. In other words, no matter how short or long the cornea appeared in the image, the data showed that the anterior hyaloid bows backward during accommodation and that with age the cleft between the pars plicata and the anterior hyaloid decreases. Readers can also examine the dynamic videos included with the paper to determine how stable the UBM probe is with respect to the eye during accommodation to make their own determinations. In addition, the video taken using an endoscopic camera (Supplementary Video S4) also demonstrates that the anterior hyaloid bows backward during accommodation.

We demonstrate how the measurements were taken from the UBM images in Figure 1 of the first (companion) paper[2] and in previous publications.[4–8] For both the monkeys and the human subjects, images were systematically collected, with the anterior/posterior ends of the ciliary body and vitreous zonule oriented in a horizontal direction within all images,[4] and the eyes were imaged at a known level of accommodative amplitude. Thus, with all due respect to Dr. Schachar, we did take baseline measurements of the intraocular structures in the resting eye using known reference points inside the eye (i.e. the distance between known landmarks, such as the scleral spur and the posterior insertion zone of the vitreous zonule) and repeated the measurements in the accommodated eye. The presence of eye movements or small differences in probe position relative to the

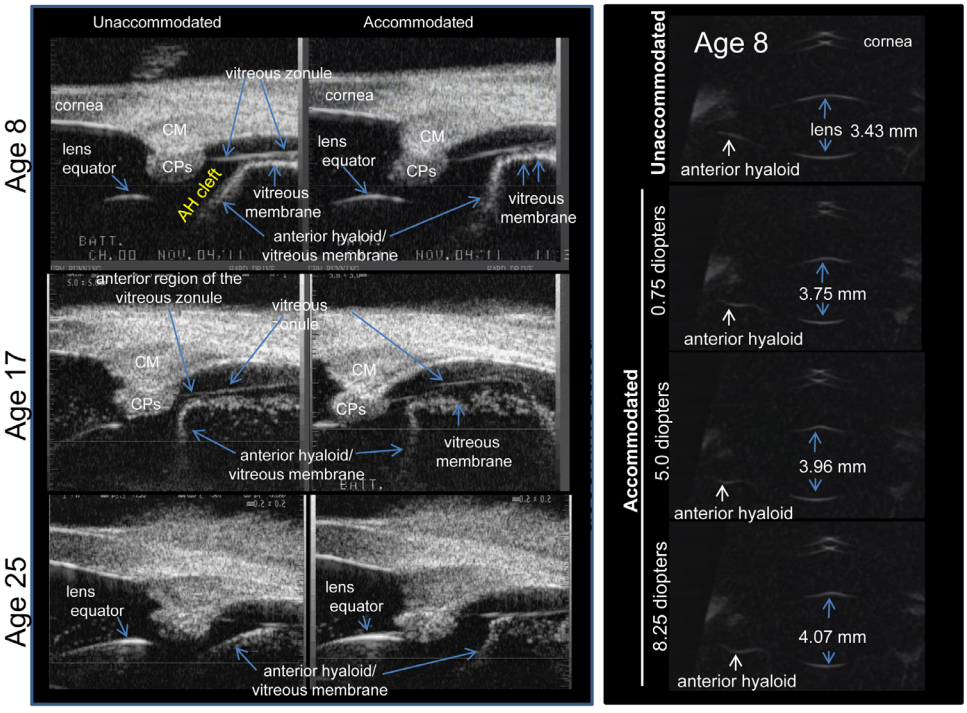

Figure 1. Left and Middle Panels. UBM images in the temporal quadrant in 8–, 17–, and 25-year-old rhesus monkeys in the unaccommodated and maximally accommodated states following injection of Triesence (triamcinolone acetonide), which clings to the vitreous membrane. Middle Panels. The anterior hyaloid relaxes/curves posteriorly during accommodation (see also Video Clips #1 and #3). The AH cleft which lies between the ciliary processes and the anterior hyaloid is reduced in the older eyes (ages 17 and 25) vs. the young eye (age 8). Right Panels. UBM images of the anterior segment in an 8-year-old rhesus monkey in the unaccommodated state and during various accommodative amplitudes. Arrow indicates the anterior hyaloid. The backward bowing of the anterior hyaloid is more pronounced as the amplitude of accommodation increases. CM=iliary muscle. CP_s-ciliary processes.

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eye may result in increased variability, but the extent of the noise introduced by eye movements or probe position (if any) is extremely small relative to the magnitude of the accommodative movements, and the data show significant differences between the groups and significant changes with age. Further, eye movements that occur with pharmacologically stimulated accommodation are not systematic but are random in nature. The accommodative responses are the same whether stimulated pharmacologically (humans) or by central electrical stimulation (monkeys).[2]

It is very clear that Dr. Schachar and others in the field have deeply held and conflicting views about the basic mechanisms of accommodation and presbyopia, as evidenced not only in his current letter but other letters he has written, as well.[9–14] The assertions by Dr. Schachar have been made before and addressed previously[15–19] and are again addressed in this letter. Dr. Schachar's criticism is basically the same for any publication that reports data that are in disagreement with his unique theory of accommodation and presbyopia.

The current letter written by Dr. Schachar is yet another example of the passionate disagreements that exist in the field regarding the basic mechanism of accommodation and presbyopia. One school of thought posits that it is the capsule that changes the shape of the lens, that the lens diameter decreases during accommodation (Helmholtz),[20] and that the lens hardens with age. Others believe that the vitreous may be involved,[21] whereas Dr. Schachar believes in a mechanism of accommodation opposite to the commonly accepted Helmholtz theory.[22] Our goal was to help understand an unappreciated aspect of the accommodative mechanism and provide a measure of the various accommodative components. Our data may provide insight into the eye's ability to smoothly track objects in the field of view. We are not trying to mediate a fight that exists in the field.

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References

1. Schachar RA. Image registration is required for experiments of accommodation. *Invest Ophthalmol Vis Sci*. 2021;62(2):17.
2. Croft MA, McDonald JP, Katz A, Lin TL, Lütjen-Drecoll E, Kaufman PL. Extralenticular and lenticular aspects of accommodation and presbyopia in human versus monkey eyes. *Invest Ophthalmol Vis Sci.* 2013;54(7):5035–5048.
3. Croft MA, Nork TM, McDonald JP, Katz A, Lütjen-Drecoll E, Kaufman PL. Accommodative movements of the vitreous membrane, choroid and sclera in young and presbyopic human and nonhuman primate eyes. *Invest Ophthalmol Vis Sci.* 2013;54(7):5049–5058.
4. Croft M, Glasser A, Heatley G, McDonald J, Ebbert T, Kaufman PL. Accommodative ciliary body and lens function in rhesus monkeys. I. Normal lens, zonule and ciliary process configuration in the iridectomized eye. *Invest Ophthalmol Vis Sci.* 2006;47(3):1076–1086.
5. Croft M, McDonald JP, James RJ, et al. Surgical intervention and accommodative responses, I: centripetal ciliary body, capsule, and lens movement in rhesus monkeys of various ages. *Invest Ophthalmol Vis Sci.* 2008;49(12):5484–5494.
6. Croft M, McDonald JP, Nadkarni NV, Lin TL, Kaufman PL. Age-related changes in centripetal ciliary body movement relative to centripetal lens movement in monkeys. *Exp Eye Res.* 2009;89(6):824–832.
7. Wasielewski R, McDonald JP, Heatley G, Lütjen-Drecoll E, Kaufman PL, Croft MA. Surgical intervention and accommodative responses, II: forward ciliary body accommodative movement is facilitated by zonular attachments to the lens capsule. *Invest Ophthalmol Vis Sci.* 2008;49(12):5495–5502.
8. Lütjen-Drecoll E, Kaufman P, Wasielewski R, Ting-Li L, Croft M. Morphology and accommodative function of the vitreous zonule in human and monkey eyes. *Invest Ophthalmol Vis Sci.* 2010;51(3):1554–1564.
9. Schachar RA. Letter to the editor: the effect of equatorial stretching of the human crystalline lens on accommodative amplitude. *Invest Ophthalmol Vis Sci.* 2003;44:77–78, http://www.iovs.org.cgi/e/letters/44/1/250.
10. Koopmans SA. Author response: the effect of equatorial stretching of the human crystalline lens on accommodation. *Invest Ophthalmol Vis Sci.* 2003;44:79–81.
11. Schachar RA. Letter to the editor: change in intralenticular pressure during accommodation. *Invest Ophthalmol Vis Sci.* 2004;45.
12. Strenk SA. Author response: change in intraocular pressure during accommodation. *Invest Ophthalmol Vis Sci.* 2004;45.
13. Schachar RA, Kamangar F, Pierscionek BK. Comment: changes in lens dimensions and refractive index with age and accommodation. *Optom Vis Sci.* 2008;85(4):281–282; author reply, 282–283.
14. Pope JM. Letter to the editor: changes in lens dimensions and refractive index with age and accommodation. *Optom Vis Sci.* 2008;85:281–283, http://www.researchgate.net/publication/5471043.
15. Croft M, Glasser A, Heatley G, McDonald J, Ebbert T, Kaufman PL. Author response: additional controls required for assessing in vivo accommodation. *Invest Ophthalmol Vis Sci.* 2006;47.
16. Schachar RA. Letter to the editor: additional controls required for assessing in vivo accommodation. *Invest Ophthalmol Vis Sci.* 2006;47(8), http://www.iovs.org/cgi/eletters/47/3/1076#375.
17. He L, Wendt M, Glasser A. Long-term reproducibility of Edingere Westphal stimulated accommodation in rhesus monkeys. *Exp Eye Res.* 2013;113:80–86.
18. Schachar RA. Comment on "Long-term reproducibility of Edingere Westphal stimulated accommodation in rhesus monkeys" by He et al. *Exp Eye Res.* 2013;115:274.
19. Glasser A. Response to Letter from Dr. Schachar. *Exp Eye Res.* 2013;115:275.

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20. von Helmholtz H. Mechanism of accommocation. In: von Helmholtz H, Southall JPC , eds. *Helmholtz's Treatise on Physiological Optics*. Washington, DC: Optical Society of America; 1924:143–172.
21. Coleman DJ, Fish SK. Presbyopia, accommodation, and the mature catenary. *Ophthalmology*. 2001;108(9):1544–1551.
22. Schachar RA, Black TD, Kash RL, Cudmore MS, Schanzlin DJ. The mechanism of accommodation and presbyopia in the primate. *Ann Ophthalmol*. 1995;27(2):59–67.

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